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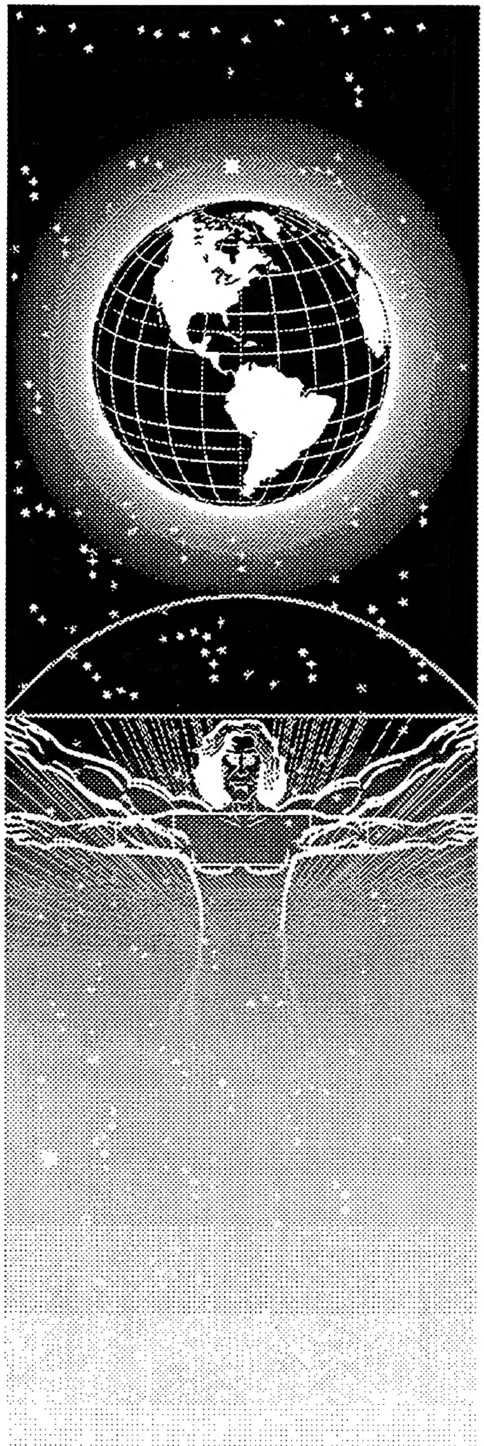

UNITED STATES AIR FORCE
ARMSTRONG LABORATORY

The Distribution of Flight Tracks Across Air Combat Command Military Training Routes

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March 1996

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13. ABSTRACT *(Maximum 200 words)*

To validate the flight track dispersion algorithms currently in the ROUTEMAP and MR_NMAP noise models, measurements of the lateral distribution of flight operations were conducted on five low-altitude Military Training (MTRs). This distribution defines the spread in aircraft position across the width of the route. Included were three instrument routes and two visual routes having various widths and flight operation characteristics. Two methods were used to determine the distribution on the MTRs; acoustic measurements and radar tracking. The first method used a linear array of noise monitors, spanning the width of the route, to record overflight noise levels and thus estimate the aircraft position along the array. Due to limitations with this procedure, radar tracking was used as an alternate method. The results, using both methods, indicate that flight tracks are distributed across MTRs in Gaussian form and the standard deviation of tracks is generally proportional to the route width. These findings support the results of previous studies which were used to develop the flight track dispersion algorithms. A recommendation has been made to formally adopt these algorithms for use in both models.

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1.0 INTRODUCTION

The Air Force, and the Air Combat Command (ACC) in particular, routinely conducts low-altitude, high-speed flight training operations. These operations occur on specially designated military training routes (MTRs) or military operating areas (MOAs). Routes are continually changed because of the need for variety, changing weapons systems and tactics, and encroachment on existing routes. Environmental assessments are required for new routes or for existing routes when a change in aircraft resources or flight operations is planned.

A series of studies on MTR noise[1-8] has led to development of the ROUTEMAP and MR_NMAP models[9,10] which are currently used for environmental assessments. One element of this research involved measurement of the lateral distribution of flight tracks on a number of routes managed by ACC as well as the Strategic and Tactical Air Commands.* This distribution is a measure of the spread in aircraft position across the route corridor. Based on these measurements, preliminary rules for modeling lateral flight track dispersion have been incorporated into the noise models. The main objective of this study was to further support the previous measurements and review (and modify, if necessary) the rules for modeling MTR flight track dispersion.

This report presents the results of measurements performed on five additional routes. Three of these routes are managed by ACC: IR-109 is located in New Mexico and scheduled through Cannon AFB, IR-302 is located in parts of Idaho and Nevada and scheduled through Mountain Home AFB, and IR-036 is located in South Carolina and scheduled through Shaw AFB. The remaining two routes are managed by the Navy; these are VR-1753 located in Virginia and scheduled through NAS Oceana and VR-1041 located in South Carolina and scheduled through MCAS Cherry Point.

Two methods were used for measuring flight track dispersion on the five MTRs: acoustic measurements and radar tracking.

Acoustic measurements were performed on the first three routes: IR-109, IR-302, and VR-1753, similar to the measurements conducted in the previous MTR studies.[2,4,5] Noise measurements were taken using as many as 30 noise monitors

* As of 1 July 1992, SAC and TAC have been reorganized into Air Combat Command (ACC).

placed laterally across the route. Each time the noise level exceeded a preset threshold, the monitors recorded the maximum A-weighted sound level, the sound exposure level, and the time and duration of the event. These data were subsequently analyzed to determine the statistical distributions of maximum sound levels (and hence aircraft tracks) across the route.

Acoustic measurements are labor intensive. In an effort to increase the yield of this project, an alternative method for measuring flight track dispersion was examined. In this case, long-range radar was used to track flight operations on a number of MTRs, MOAs, and Restricted Areas. The FAA radar facility in Jedburg, South Carolina, was used to obtain flight tracking information for airspace operations occurring within a 100-nautical-mile radius. Data analysis was performed to determine the statistical distribution of flight tracks on IR-036 and VR-1041. A qualitative discussion is presented for flight tracks measured in the Restricted Area R-6002 and Gamecock C MOA.

The key findings of the study are as follows:

- Flight tracks are distributed across MTRs, with the distribution having a Gaussian form. This is the same result as in References 2, 4, and 5.
- The standard deviation of flight tracks varies with route width. The relationship between standard deviation and width is presented, together with recommended rules for selecting appropriate values for various situations.

Results of this study were shown to support the existing flight track dispersion algorithms used in the ROUTEMAP and MR_NMAP models. A recommendation has been made to the Air Force, AL/OEBN, to formally adopt these algorithms for use in both noise models.

Section 2 of this report provides a description of MTRs and current ACC low-level training operations. Section 3 introduces the use of radar tracking data to study flight operations on special-use airspaces and presents the results of flight track dispersion measurements on two MTRs. Section 4 contains a description of the acoustic measurement program and analysis used to determine the flight track dispersion on three MTRs. The conclusions of this study are presented in Section 5. Appendix A describes audio recordings made for the F-16C Block 52, F-15E, and F-4G aircraft operating at MTR flight conditions. The recordings are used to determine the source noise levels of these aircraft for the ROUTEFILE database.

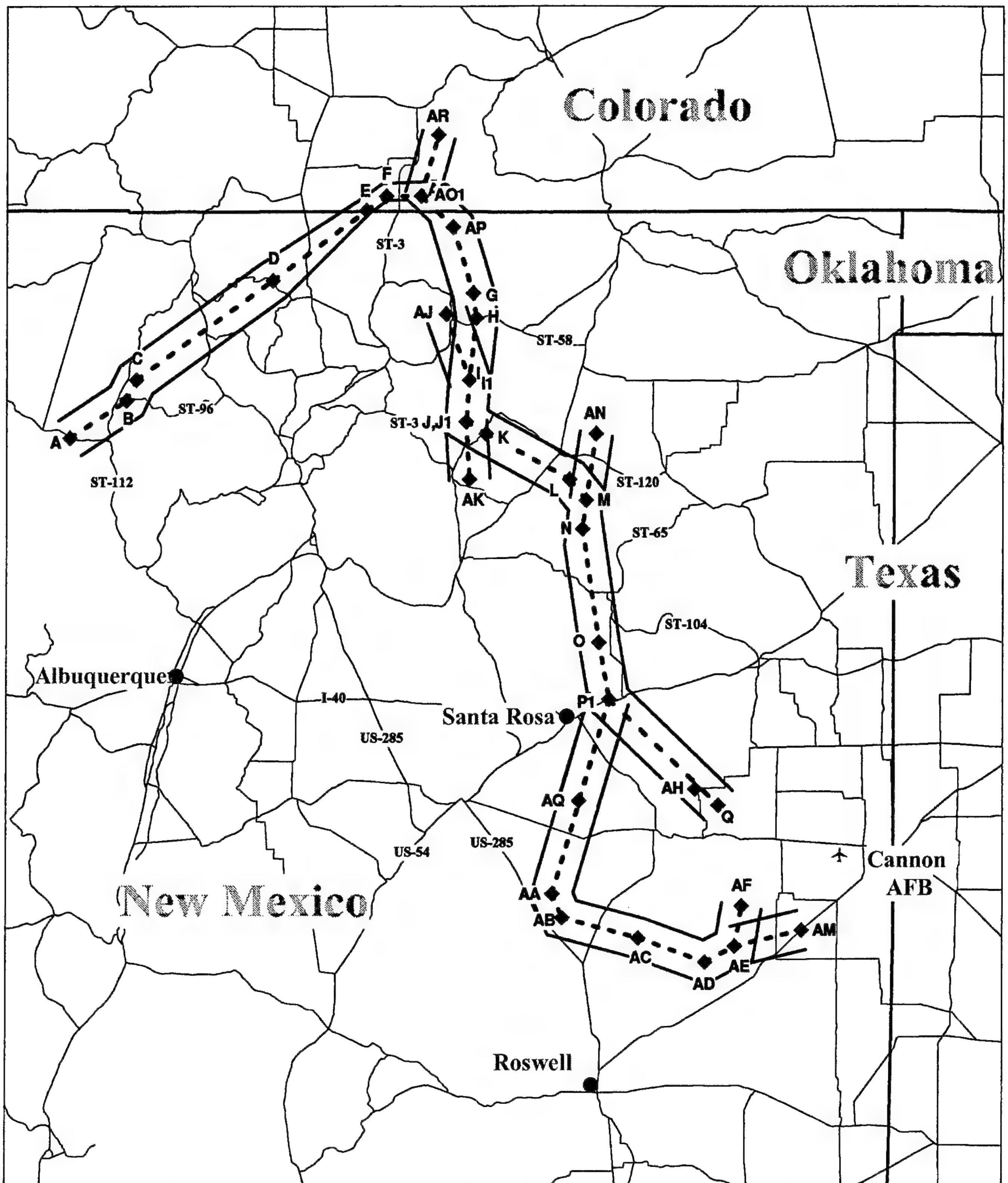
2.0 ACC MILITARY TRAINING ROUTE CHARACTERISTICS

2.1 MTR Airspace Description

A Military Training Route (MTR) is a defined volume of airspace designed for use by military aircraft which can generally be described as having an altitude structure below 10,000 feet mean sea level (MSL) and varying width along the different airspace segments (linear sections of the MTR defined by the coordinates of the route centerline and the route width). MTRs are divided into three sub-types: visual routes (VRs), instrument routes (IRs), and slow routes (SRs). Operations on visual routes are conducted only when the weather is at or above Visual Flight Rule minimums of five miles or more visibility and a weather ceiling of 3,000 feet or more. Operations on instrument routes can be conducted in instrument meteorological conditions. Military aircraft on VRs and IRs can operate at speeds in excess of 250 knots indicated airspeed (KIAS). Slow routes are used for military aircraft operations at or below 1,500 feet at airspeeds of 250 knots or less.

The Department of Defense publishes a guide entitled "Area Planning – Military Training Routes – North and South America (AP/1B)" which contains the definitions and operating instructions for all MTRs.[11] This document defines each MTR by airspace segment and lists the latitude and longitude of the start and end points, the altitude profile (floor and ceiling), and the route width. On many routes the minimum published altitudes are as low as 100 feet AGL or down to the surface. Higher limits based on obstacle clearance imposed by Air Combat Command may supersede these limits. While a route may be entered or exited at a number of designated points, use of the primary entry and exit points is more typical. Route widths vary, based on factors such as clearance of known obstacles, avoidance of noise-sensitive areas (such as population centers and recreational areas), etc. Typical widths range from 4 to more than 10 nautical miles, but can be more than 20 nautical miles wide. There is no formal lateral constraint except to remain within the route boundaries.

Figure 2-1 depicts IR-109, a typical ACC route located in eastern New Mexico. Shown are the edge boundaries and route centerline. The centerline is defined by points A through Q, along with additional alternate entry and exit points. The edge



Scale

0 20 40

Miles

N

Legend

MTR Boundary
MTR Centerline
Cannon AFB
City/Town

Figure 2-1

Low-Altitude ACC Route: IR-109

boundaries are defined by the route width as described about the centerline. Figure 2-2 is the published description of IR-109 taken from the AP/1B planning guide.[11] This route contains more alternate entry and exit points than is common; however, the majority of the flight activity utilizes the primary entry and exit points A and Q, respectively. The route width between these points varies from as low as 4 nautical miles at point F to 10 nautical miles at point Q.

2.2 ACC Flight Training Mission Profiles

The Air Combat Command conducts high-speed, low-altitude training missions under visual and instrument flight rules. One objective of these missions is to practice low-altitude, point-to-point navigation at altitudes as low as 100 feet above ground level (AGL) and air speeds typically up to 540 knots. High-speed ACC aircraft include F-4s, F-111s, F-15s, and F-16s. Navy, Marine, Air National Guard, and Reserve units routinely fly similar missions on many of the same or similar routes. Fighter aircraft frequently operate in multiple-ship formations, which can be spaced over a mile in width. A typical two-ship formation is line abreast, where the aircraft are relatively even with each other but laterally separated by 6,000 to 9,000 feet. An alternative is for the second aircraft to fly in trail, 10,000 to 15,000 feet behind the leader. On occasion, two aircraft will fly in a close echelon formation, separated by a few hundred feet, but this is relatively uncommon at low altitude. Four aircraft may fly in a box formation, consisting of two lines abreast with the second line following the first by 10,000 to 15,000 feet. Wide formations tend to change structure, then reform as they negotiate turns, mountain passes, ridges, etc.

Prior to a mission, a route map is prepared by each pilot. This contains the route outlines along with notes on headings, obstacles, and areas to avoid. A sample route map for IR-109, near point P, is shown in Figure 2-3 oriented similar to Figure 2-1. A path is drawn between navigation points within the boundaries of the MTR. These navigation points appear as circles in Figure 2-3 and frequently correspond to prominent landmarks.

Recommend flight at 1000' AGL or above during these periods to reduce bird strike hazard.
(15) Avoid by 1 NM and 1000' AGL uncharted active airport at 36°04'56"N 104°25'00"W (CANYON, CO./CANADIAN RIVER).
(16) CAUTION - Camco Ranch missplotted on TPC's and sectional. Avoid Camco Ranch Airstrip - 35°34'30"N 103°18'30"W 1000' AGL and 1 NM.

FSS's Within 100 NM Radius:

ABQ, CNM, LVS, MAF, ROW, TCC

IR-109

ORIGINATING ACTIVITY: 27 OSS/OSOH 110 E. Sextant Ave. Suite 1081 Cannon AFB, NM 88103 DSN 681-2279.

SCHEDULING ACTIVITY: 27 OSS/OSOS 110 E. Sextant Ave. Suite 1080 Cannon AFB, NM 88103. Request must be 24 hr in advance. For weekend use call 1430-2300Z++ Mon-Fri DSN 681-2276.

HOURS OF OPERATION: Continuous.

ROUTE DESCRIPTION:

Altitude Data	Pt	Fac/Rad/Dist	Lat/Long
160 MSL or as assigned at	A	ABQ 332/65	36°05.0'N 107°10.0'W
01 B 120 MSL to	B	ABQ 344/71	36°14.0'N 106°53.0'W
01 B 120 MSL to	C	ABQ 346/76	36°19.0'N 106°50.0'W
01 B 120 MSL to	D	ALS 190/41	36°43.0'N 106°09.0'W
01 B 120 MSL to	E	ALS 150/22	37°00.0'N 105°41.0'W
01 B 120 MSL to	F	ALS 134/21	37°03.5'N 105°35.0'W
01 B 120 MSL to	AO	ALS 119/26	37°03.5'N 105°24.5'W
01 B 150 MSL to	AP	ALS 119/37	36°56.0'N 105°15.0'W
01 B 150 MSL to	G	CIM 295/17	36°40.0'N 105°09.0'W
01 B 150 MSL to	H	CIM 277/13	36°34.0'N 105°08.0'W
01 B 150 MSL to	I	CIM 221/18	36°19.0'N 105°10.0'W
01 B 150 MSL to	J	CIM 204/25	36°09.0'N 105°11.0'W
01 B 150 MSL to	K	LVS 352/27	36°06.0'N 105°05.0'W
01 B 120 MSL to	L	LVS 043/28	35°55.0'N 104°40.0'W
01 B 120 MSL to	M	LVS 055/29	35°50.0'N 104°35.0'W
01 B 90 MSL to	N	LVS 069/26	35°43.0'N 104°36.0'W
01 B 80 MSL to	O	TCC 263/45	35°15.0'N 104°31.0'W
01 B 70 MSL to	P	TCC 245/44	35°01.0'N 104°28.0'W
01 B 70 MSL to	Q	CVS 281/32	34°35.0'N 103°55.0'W
Alternate Transition Routing to R-5104 IR-109 South			
As assigned to	P1	TCC 245/44	35°01.0'N 104°28.0'W
01 B 70 MSL to	AA	CME 341/53	34°13.0'N 104°45.0'W
01 AGL B 70 MSL to	AB	CME 343/47	34°07.0'N 104°42.0'W
01 AGL B 70 MSL to	AC	CME 008/44	34°02.0'N 104°19.0'W
01 AGL B 70 MSL to	AD	CVS 219/42	33°56.0'N 103°59.0'W
01 AGL B 70 MSL to	AE	CVS 216/34	34°00.0'N 103°50.0'W
01 AGL B 70 MSL to	AF	CVS 230/27	34°10.0'N 103°48.0'W
to R-5104/R-5105			
North Race Track: Exit R-5104/R-5105 at or below 70 MSL			
01 AGL B 70 MSL to	AFI	CVS 230/27	34°10.0'N 103°48.0'W
01 AGL B 70 MSL to	AE1	CVS 216/34	34°00.0'N 103°50.0'W
01 AGL B 70 MSL to	AG	CVS 227/44	34°00.0'N 104°04.0'W
01 AGL B 70 MSL to	AH	CVS 283/39	34°39.0'N 104°02.0'W
01 AGL B 70 MSL to	AI	TCC 184/33	34°39.0'N 103°47.0'W
to R-5104/5105			
South Race Track: Exit R-5104/5105 at or below 70 MSL to			
01 AGL B 70 MSL to	AI1	TCC 184/33	34°39.0'N 103°47.0'W
01 AGL B 70 MSL to	AH1	CVS 283/39	34°39.0'N 104°02.0'W
01 AGL B 70 MSL to	AG1	CVS 227/44	34°00.0'N 104°04.0'W
01 AGL B 70 MSL to	AE2	CVS 216/34	34°00.0'N 103°50.0'W
01 AGL B 70 MSL to	AF2	CVS 230/27	34°10.0'N 103°48.0'W
to R-5104/R-5105			
Alternate Entry: I			
160 MSL or as assigned at	AJ	CIM 273/21	36°35.0'N 105°17.0'W
01 AGL B 150 MSL to	I1	CIM 221/18	36°19.0'N 105°10.0'W
Then via IR-109			
Alternate Entry: M			
170 MSL or as assigned at	AN	LVS 035/40	36°06.0'N 104°32.0'W
Descend to cross at 01 AGL B 90 MSL then via IR-109 or IR-109 South	M1	LVS 055/29	35°50.0'N 104°35.0'W
Alternate Exit: J			
150 MSL at	J1	CIM 204/25	36°09.0'N 105°11.0'W
Proceed direct to	AK	LVS 341/16	35°55.0'N 105°10.0'W
(Contact Albuquerque ARTCC on 353.8)			
Alternate Exit: AO			
01 B 120 MSL to	AO1	ALS 119/26	37°03.5'N 105°24.5'W
(Contact Denver ARTCC on 379.95)			
Climb to Cross at 160 MSL	AR	ALS 083/24	37°18.4'N 105°19.4'W
Alternate Exit: P			
70 MSL or below at	P2	TCC 245/44	35°01.0'N 104°28.0'W
70 MSL to	AL	TCC 247/29	35°05.0'N 104°11.0'W
Flight plan route			
(Contact Albuquerque ARTCC on 319.2)			
Alternate Exit: AE			
01 AGL B 70 MSL at	AE3	CVS 216/34	34°00.0'N 103°50.0'W
70 MSL to	AM	CVS 193/21	34°04.0'N 103°30.0'W
Contact Cannon RAPCON on 358.3 leaving 61 MSL.			
Alternate Exit: AQ			
70 MSL or below at	P1	TCC 245/44	35°01.0'N 104°28.0'W
Climb to cross at 70 MSL or assigned	AQ	CME 348/76	34°36.0'N 104°37.0'W
(Contact ZAB ARTCC on 319.2 for transition to VR-1195 or Pecos MOAS).			

TERRAIN FOLLOWING OPERATIONS: Authorized entire route.

ROUTE WIDTH - 5 NM either side of centerline from A to E; 3 NM left and 1 NM right of centerline from E to AO; 5 NM left and 3 NM right of centerline from AO to AP; 5 NM either side of centerline from AP to end of route; 5 NM either side of centerline for Alternate Entry I and Exits J, P, and AE; 4 NM either side of centerline for Alternate Entry M. Alternate Exit AO: 3 NM left and 1 NM right of centerline from F to AO, 4 NM either side of centerline from AO to AR, Re-Entry: R-5104/5105; 7.5 NM either side of centerline on Re-Entry pattern AF1 to AI, AI1 and AF2.

Special Operating Procedures:

(1) Non 27 TFW aircraft entry times are booked no closer than 15 minutes apart. Users must meet booked entry and exit times plus or minus 5 minutes. If unable to meet planned entry time enter at an Alternate Entry so as to meet booked exit time or do not enter the route. Route times are planned at 480 kts ground speed.
(2) Aircraft must call in-the-blind route entry and exit On 255.4. Monitor 255.4 while on this route unless operational requirements dictate otherwise.

Figure 2-2. IR-109 Route Description.

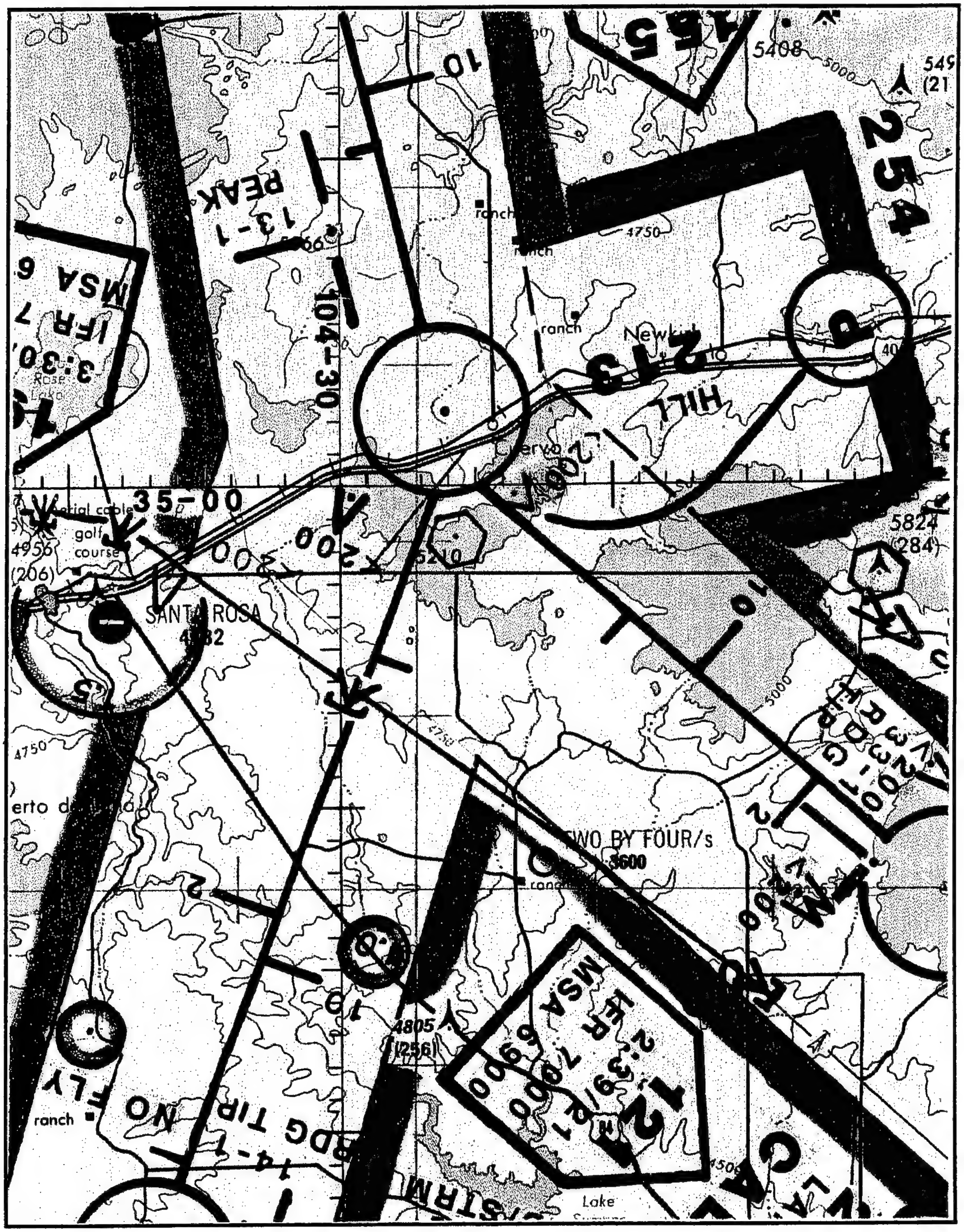


Figure 2-3. IR-109 Route Map.

2.3 Operations and Scheduling

The busiest ACC routes experience up to 3,000 sorties per year. Based on 200 flying days per year, there would be an average of 10 to 15 sorties (grouped in three to five missions) per day on these busy routes. Minimum separation between flights is five minutes, although the average time between flights is much greater. Each flight is essentially an isolated event, so there is no reason to expect mission profiles on busy routes to differ from those on lightly used ones.

Scheduling activity for ACC routes is mostly decentralized, with responsibility handled by the primary route user. Route descriptions in the AP/1B guide[11] identify the scheduling activity. The purpose of scheduling is to avoid conflicts between users without unreasonably restricting the flexibility and initiative implicit to tactical air operations. One use of schedule information is to assess the utilization of various routes, and thereby aid airspace planning. Schedule data is of interest in the current project, recognizing that scheduling data is not collected for purposes of analysis.

Scheduling is performed with various degrees of advance and short-term planning. Reservation of specific time slots for particular missions frequently takes place the day before or the morning of a mission. However, same-day scheduling can occur up to time of entry into a route. Actual route entry times are usually within 10 minutes of scheduled times. The schedule log will usually not reflect this same-day scheduled activity, nor will it account for mission cancellations.

3.0 THE USE OF RADAR TRACKING DATA TO STUDY MILITARY AIRCRAFT FLIGHT OPERATIONS ON SPECIAL-USE AIRSPACES

3.1 Introduction

The objective of this study was to quantify the lateral distribution of flight tracks on MTRs and develop rules for modeling flight track dispersion. Recent studies[2,4,5] of flight track dispersion were based on acoustic measurements of low-altitude military aircraft overflights on a variety of MTRs. For each MTR, a linear array of noise monitors, spanning the width of the route, was used to record the overflight noise levels and thus determine the aircraft position along the array. While Section 4.0 reports new results using this procedure, it is worth noting a number of limitations: (1) measurements can only be obtained for one cross-section of the route due to the large number of noise monitors required; (2) altitude, velocity, and other flight parameters cannot be measured; (3) not all flight activity can be positively identified; and (4) other inherent difficulties associated with conducting a field measurement program (i.e., weather, security, etc.). Because of these limitations, an alternative method for measuring flight track dispersion was also utilized.

This section details the use of radar tracking data to study aircraft flight operations on special-use airspaces. Flight track dispersion measurements are provided for two MTRs, IR-036 and VR-1041. In addition, a qualitative discussion of flight activity on Restricted Area R-6002 and the Gamecock C MOA is presented.

While some limitations have been mentioned regarding the use of acoustic measurements to study flight track dispersion, there are many advantages to using radar for the measurements. The use of radar allows measurements to be performed in any size airspace, provided it lies within the radar coverage. For example, some MTRs have published route widths greater than 20 nautical miles. To perform an acoustic measurement on a 20-nautical-mile-wide route would require eighty noise monitors spaced one-quarter nautical mile apart. Also, the altitudes at which military aircraft operate are a factor in the environmental assessment process. Because of a lack of detailed information on altitude profiles, most noise assessments of MTRs and MOAs are prepared using nominal altitude distributions. Therefore, a rule pertaining to vertical flight track dispersion would potentially improve the accuracy of the process or at least make results more uniform. The use of radar

is well suited to study vertical dispersion. While the acoustic measurements are limited to one linear array that can be placed at a single point along the route, radar can potentially track operations throughout the entire airspace. In the case of MTRs, this can provide both horizontal and vertical flight track dispersion measurements at multiple points along the route which can be used to confirm mission objectives and provide detailed profiles for more accurate assessment.

Some disadvantages of using radar for this type of measurement, and primary reasons for conducting the acoustic measurement programs, are that many MTRs and MOAs are not located within radar coverage or the surrounding terrain blocks radar coverage. In order for radar to track an aircraft, the line-of-sight between the radar and aircraft must not be obstructed.

The FAA is the agency responsible for several hundred long-range radars that are located across the continental United States. These radars have a range of approximately 200 nautical miles. Most radar installations have two kinds of radar: a primary radar and a secondary radar. The purpose of the primary radar is to obtain the altitude and heading of an aircraft by transmitting a high-energy beam and detecting the return. A secondary radar transmits a signal that is picked up by the transponder on the aircraft which, in turn, sends a coded message back to the radar installation. This coded message from the transponder includes the altitude, aircraft speed, and the beacon and Mode codes used for identification. This information is combined with the data collected by the primary radar to form a message that is often called a "feed." The message is transmitted via computers and telephone lines to airspace controllers throughout the United States.

This study was conducted from 10 October through 10 December 1995. Radar data were obtained from Shaw AFB each week, along with flight operation schedules from airspace managers. The following sections describe the study area, data collection and analysis procedures, and the results.

3.2 Special-Use Airspaces Located Within the Study Area

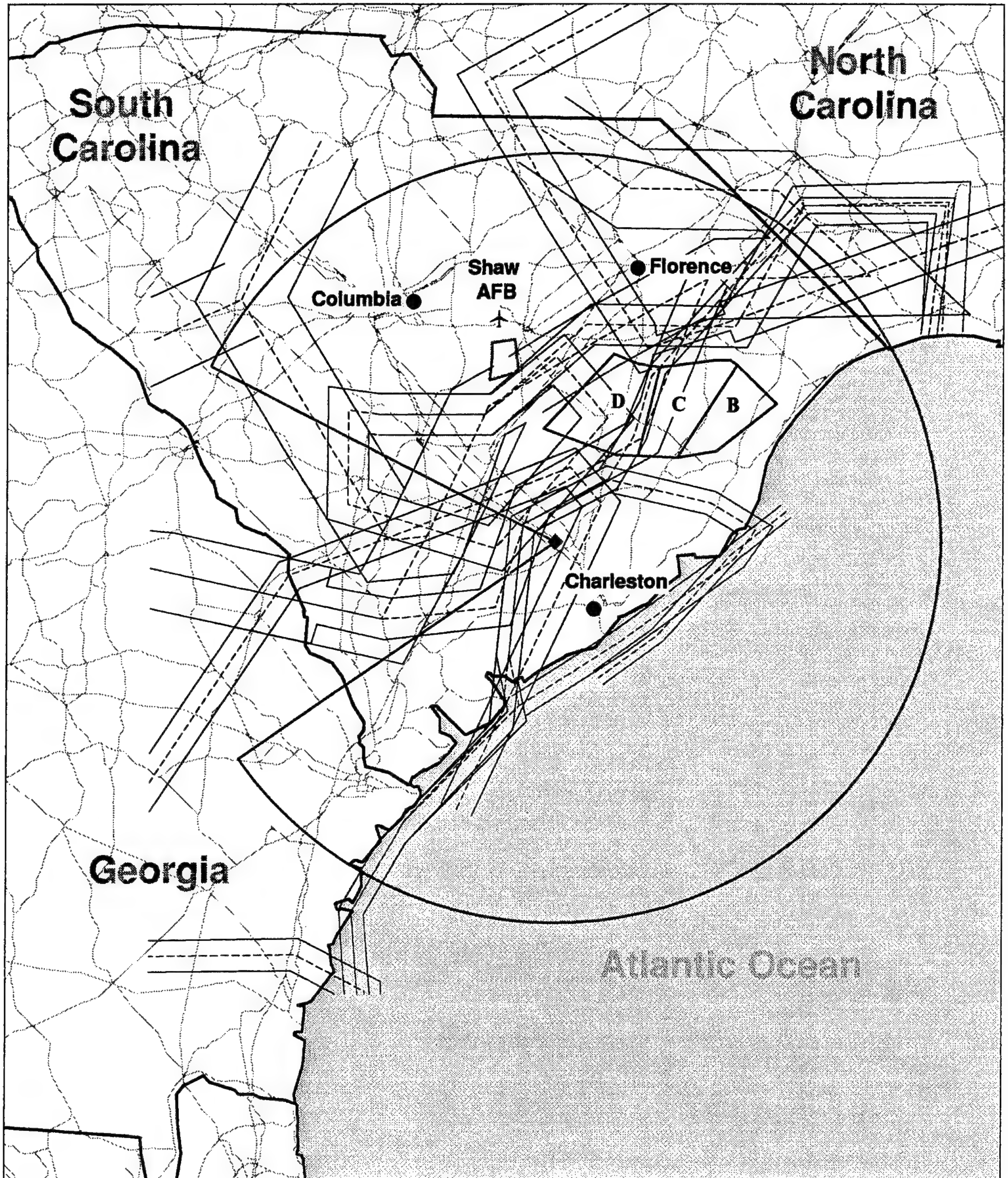
To successfully track low-altitude military flight operations with radar, the terrain must be relatively flat throughout the measurement area. A region south of Shaw AFB in South Carolina provided a useable study area where the surrounding terrain elevation was primarily at sea level. This area hosts a number of MTRs,

MOAs, and restricted areas that are operated through Shaw AFB and MCAS Cherry Point. Figure 3-1 depicts this study area, showing most of the special-use airspaces that are within the coverage provided by the FAA radar in Jedburg, SC. A total of 15 airspaces are indicated. Restricted Area R-6002 and the Gamecock B, C, and D MOAs are identified. The 11 MTRs are not labeled; however, they will be identified as necessary.

The scheduling organizations for each of the 15 airspaces are as follows: Restricted Area R-6002, Gamecock B, C, and D MOAs, IR-035, IR-036, IR-718, VR-087, VR-088, VR-097, VR-1013, and VR-1059 are scheduled through Air Traffic Control, Shaw AFB; VR-1040 and VR-1041 are scheduled through MCAS Cherry Point; and IR-018 is scheduled through Air Traffic Control, FACSFACJAX, Jacksonville, FL. Throughout the study, flight operation schedules for each airspace were provided through these organizations. As will be described in Section 3.3, radar flight track information was correlated with the schedules to aid in identifying military aircraft operations.

At the end of the two-month monitoring period it was observed that IR-018 and VR-1013 had few operations, scheduled or observed. While no operation schedules were collected for IR-718, a review of the radar data for this airspace indicated that few operations had occurred. Due to a lack of operations, these three routes were eliminated from further analysis. Also, as Figure 3-1 indicates, there was a blank spot in the radar coverage west of the Jedburg radar facility. Throughout the radar monitoring period, a new radar tower was being installed at Jedburg. For safety reasons, workers turned off the primary and secondary radar in this sector from 0700 to 1700 hours. This affected measurements on VR-088, VR-097, and VR-1059. These routes and VR-087 are also located mostly outside of the radar coverage area such that a limited number of flight tracks were observed in the analysis region. As a result, these four routes were also eliminated from further analysis.

Radar flight tracks were observed on IR-036, IR-035 (mainly the segments that are coincident with IR-036), VR-1041, Restricted Area R-6002, and the Gamecock B, C, and D MOAs. Figure 3-2 shows each of these airspaces within the radar coverage. Figure 3-3 provides the altitude utilization for each airspace,



Scale

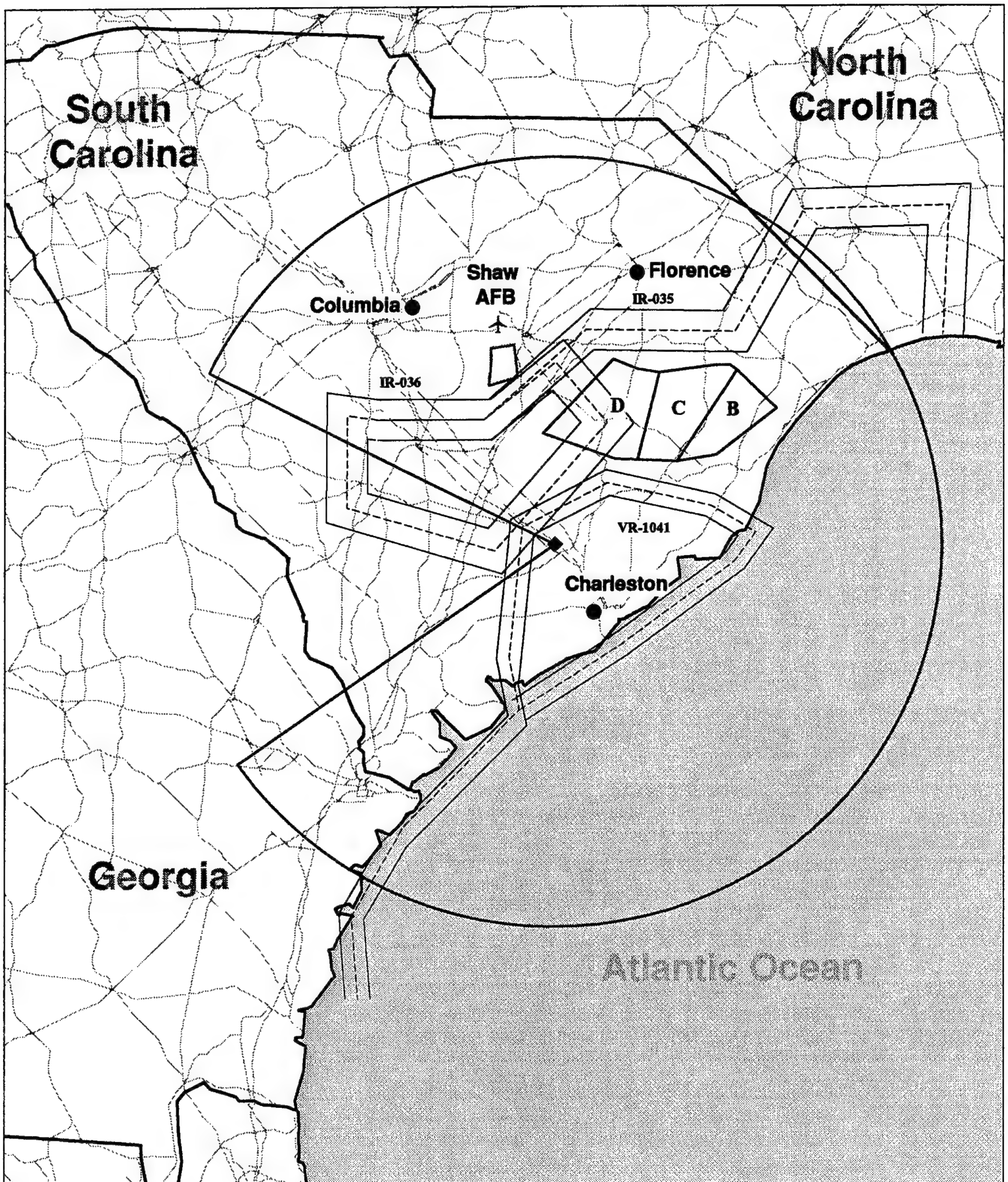
0 20 40
Miles

Legend

- MTR Boundary
- MTR Centerline
- Restricted Area R-6002
- Gamecock B, C, & D MOA
- Radar Position
- Radar Coverage

Figure 3-1

Airspace Coverage by Radar



Scale

0 20 40

Miles

N

Legend

- MTR Boundary
- MTR Centerline
- Restricted Area R-6002
- Gamecock B, C, & D MOA
- Radar Position
- Radar Coverage

Figure 3-2

Airspace Components in Study

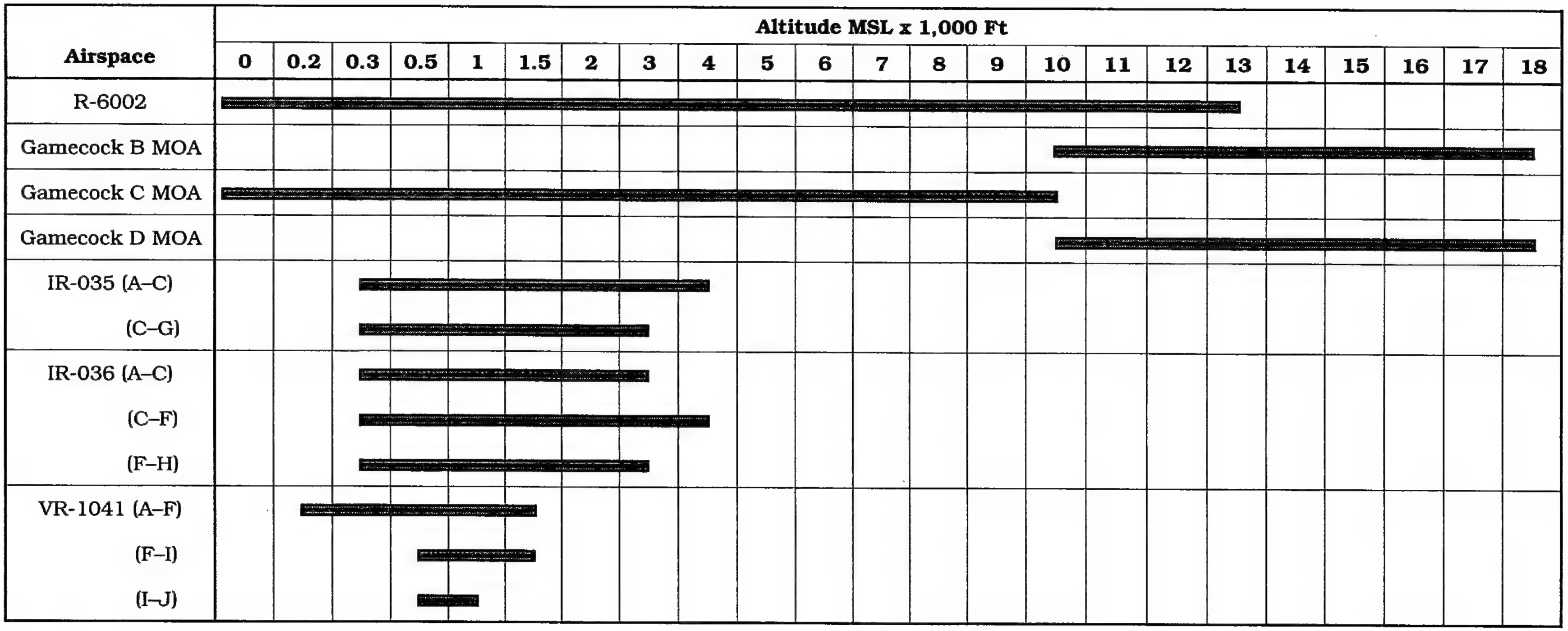


Figure 3-3. Airspace Altitude Utilization.

indicating a wide spread in the allowable regions of operation. Since the terrain elevation is primarily at sea level, all altitudes are reported in feet MSL. IR-035 and IR-036 are cleared down to 300 feet MSL with a ceiling of 3,000 or 4,000 feet MSL at various points. VR-1041 is cleared down as low as 200 feet MSL with a ceiling at 1,000 or 1,500 feet MSL. Restricted Area R-6002 and the Gamecock C MOA are cleared from the surface up to 13,000 and 10,000 feet MSL, respectively. The Gamecock B and D MOAs are high-altitude MOAs extending from 10,000 to 18,000 feet MSL.

3.3 Radar Data Collection and Analysis

Data were collected at Shaw AFB five days a week during the monitoring period of 10 October through 10 December 1995. The radar used in this study was an ASR-9 (Area Surveillance Radar) located at the FAA radar facility in Jedburg, South Carolina. The antenna's latitude and longitude are 33°04'13"N and 80° 13'13"W, respectively. This facility provides a "feed" to the Advance Tracking System (ATS) at Shaw AFB.

To retrieve data from the ATS, Wyle Laboratories contracted with Litton, Inc. to provide a personal computer interface to the ATS IEEE-488 bus. Raw radar data were downloaded to ASCII data files which were transferred, on a weekly basis, from Shaw AFB to the Wyle–Arlington, Virginia facility. A total of 1.5 gigabytes of data were received on 100 megabyte IOmega zip disks; these data were copied to a personal computer for analysis and then archived.

The radar data files contained records of flight operations which were organized sequentially according to the times at which aircraft were detected. Each record included the altitude, radar azimuth, distance from the radar to the aircraft, airspeed, flight number, beacon code, and the time. The radar assigns each aircraft a flight number for tracking purposes; however, if the aircraft is not detected on a particular sweep, a new track number can be assigned the next time the aircraft is detected.

Analysis of the radar data required the development of six computer programs to process the data. Figure 3-4 provides a flowchart of the data analysis process. Each block appearing in the figure represents a computer program. The arrows show the order of the analysis and indicates the data files that were passed between each of the programs.

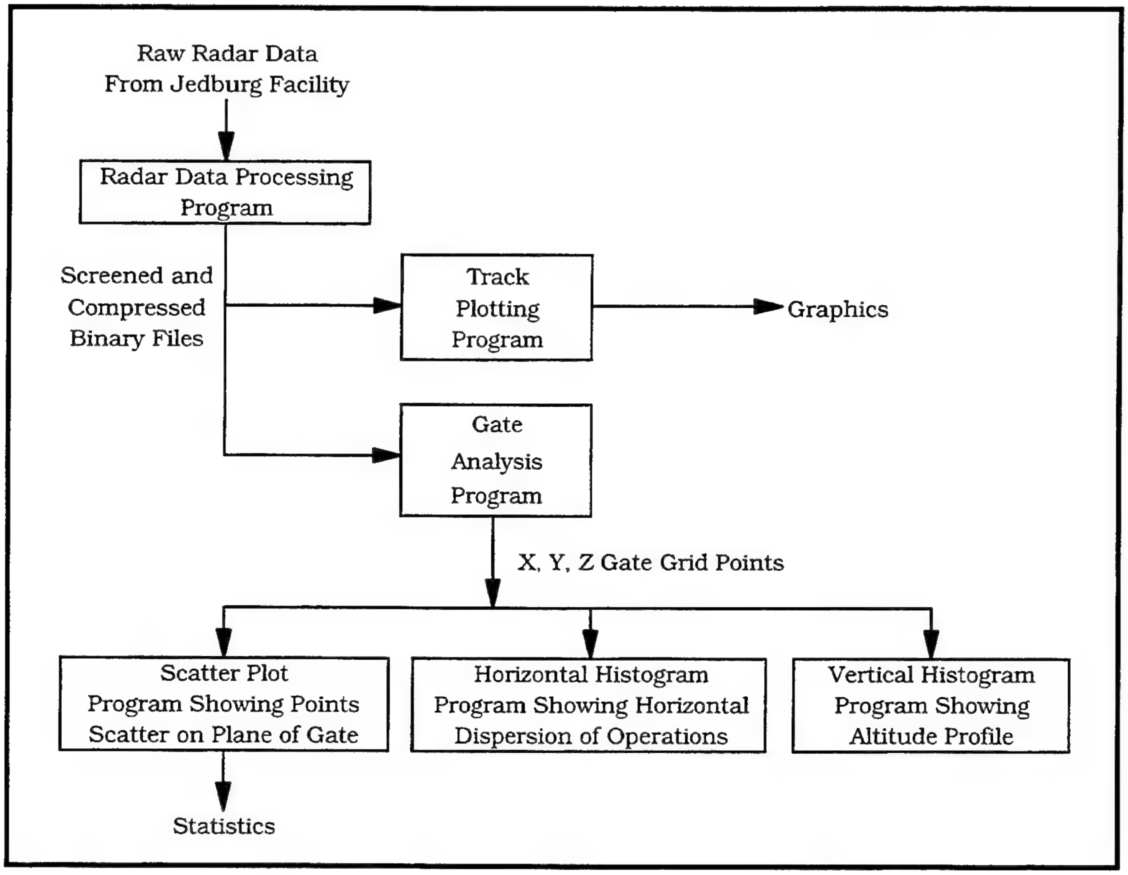


Figure 3-4. Radar Data Analysis Procedure.

The radar data processing program screened the raw radar data for errors, eliminating bad data from the sample. The most frequent source of error was due to an incomplete or corrupt data field. More than 90 percent of the data passed all of the screening tests. This program also grouped all the data points associated with each unique flight track number representing a single flight track. This data had previously been scattered throughout the ASCII files recorded at the time of radar intercept. Finally, the processing program output the collated data to a compressed binary file that was used in all subsequent data processing. Seventy-two compressed binary files, having a total size of 275 megabytes, were created from the raw radar data. Each binary file represents several hours of sampling.

The binary files were processed by two computer programs. The first program, indicated in Figure 3-4, was used to plot the ground tracks. The track plotting program has the capability of filtering the ground tracks by altitude range,

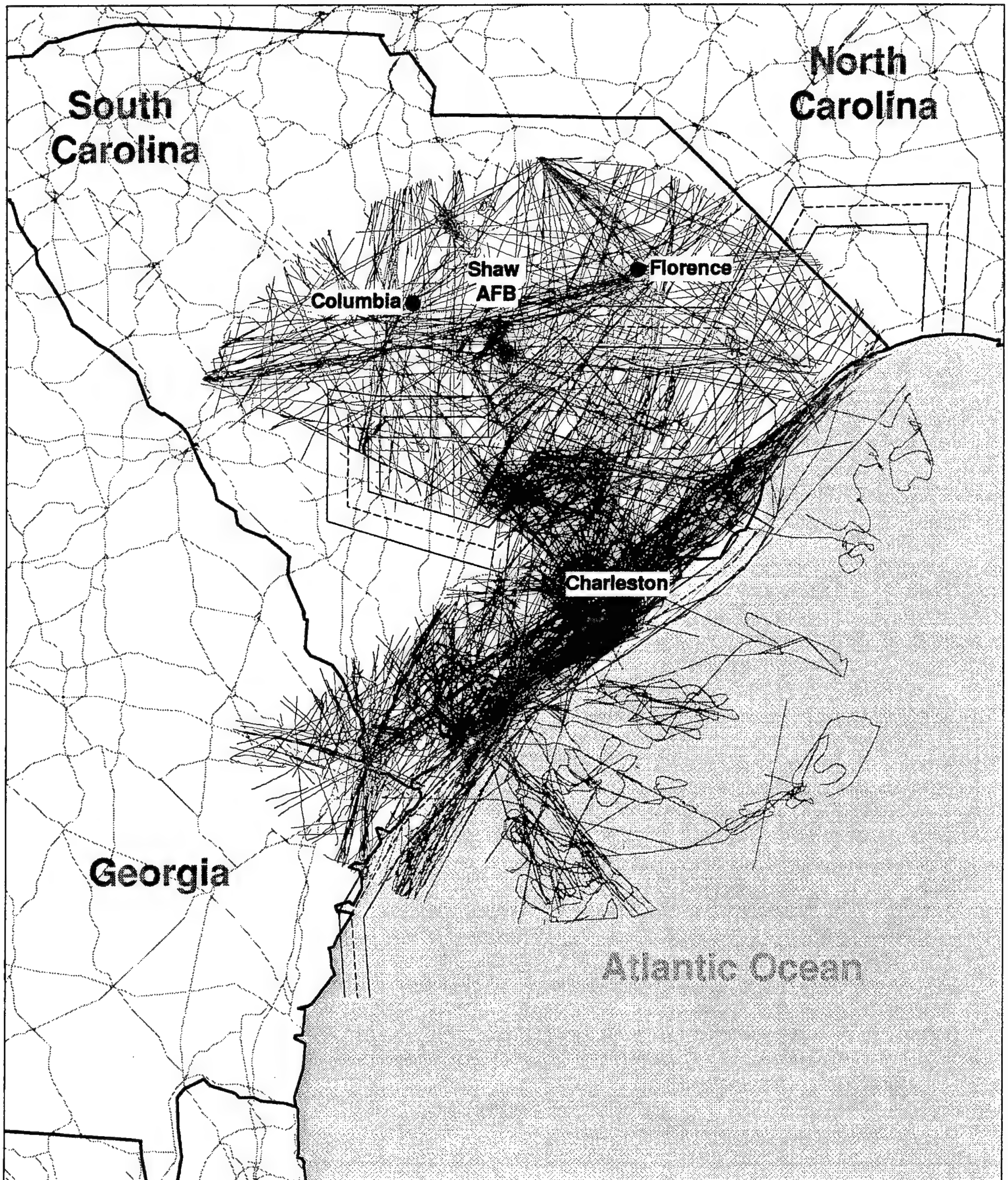
lateral boundaries, airspeed, etc. The second program was used to develop a two-dimensional representation of the horizontal and vertical distribution of flight activity within a plane situated in an airspace. The gate analysis program read the binary tracking data for each sortie, determined the exact position of the aircraft as it intersected the plane of the gate, and wrote a file containing the intercept points.

The file containing the intercept points was read by three computer programs. The first program plotted the points as they appeared on the plane of the gate. This plot, sometimes called a scatter plot, is useful in identifying horizontal or vertical dispersion patterns. The second program plotted a histogram of the horizontal dispersion of aircraft, while the third program plotted a histogram of the vertical dispersion.

A sample of unfiltered flight tracks, representing several hours of data collected on 6 November 1995, is shown in Figure 3-5. Noticeable is the blank wedge-shaped area west of the radar position, representing the inoperable radar sector. The legend provides a color scheme describing the altitude regions for the flight tracks. While there is flight activity present in all the defined altitude blocks, the high-altitude, civil air traffic is most visible with several dense flight corridors corresponding to defined civilian air traffic control routes. There also appears to be some military flight activity in Warning Areas W-134 and W-177 located off the South Carolina coast over the Atlantic Ocean. In these regions, the flight tracks indicate sharp turns and maneuvers by fighter aircraft performing air combat training. Typically present are: F-16s from Shaw AFB, F-15s from Seymour Johnson AFB, as well as Navy or Marine F-18s, F-14s, AV-8s, and E-6s from NAS Oceana.

To analyze the large amount of data collected, three processing techniques were developed as part of the track plotting and gate analysis programs mentioned above:

1. The boundaries for each of the 15 airspaces, shown in Figure 3-1, were integrated into the programs, with the ability to activate any combination of airspaces for analysis. All MTRs were described using the lateral boundary coordinates and altitude restrictions specified in the AP/1B planning guide.[11] The boundaries for Restricted Area R-6002 and the Gamecock B, C, and D MOAs were obtained from the FAA Part 73,



Legend

- MTR Boundary
- MTR Centerline
- SFC to 500 Feet MSL
- 500 to 2000 Feet MSL
- 2000 to 5000 Feet MSL
- 5000 to 20000 Feet MSL

Figure 3-5

Sample of Unfiltered Radar Tracks

Special-Use Airspace Designations.[12] These boundaries were used to filter flight tracks for each airspace. The entire set of radar tracking data (275 megabytes) was tested, one track at a time, for penetration within each airspace. If penetration occurred, all data associated with that flight track were written to a separate binary file designated for the specified airspace. Further analysis of each airspace was performed using only the associated flight track data file. These files were generally 15 to 20 megabytes in size.

2. After displaying the filtered radar tracks for each airspace, it was clear that much of the flight activity was not associated with military operations (i.e., in various MTRs, many flight tracks were observed that did not follow the corridor but crossed the airspace laterally en route to other destinations). To filter out these flight tracks, a system of gates was constructed for each MTR. Each gate spanned the width of the MTR and had a vertical span corresponding to the altitude limits for the pertinent route segment. The use of two gates to filter unwanted flight tracks and reveal potential MTR operations worked well; the requirement that the flight track penetrate both gates ensured that the track was following the MTR corridor, provided the gates were spaced far enough apart (at least 10 nautical miles).

3. While the gate analysis detected flight tracks that followed the airspace corridor, additional information was needed to confirm that these were, in fact, MTR events. As radar tracks penetrated one of the gates, the date, time, altitude, airspeed, beacon number, and track number were written to a data file which was then compared with operation schedules provided by the airspace managers. These schedules listed the following for each MTR: date, entry time, route entry point, number and type of aircraft in the mission, exit time, route exit point, and a nominal value for the airspeed. The date and time of the radar tracks were correlated with the operation schedules, and the measured airspeed was compared to the nominal airspeed value for each mission. While there were some unscheduled events in each airspace, these exhibited similar flight patterns to the identified events, and hence were retained for final analysis.

The following sections present the results of the radar study for MTRs IR-036, IR-035, and VR-1041, Restricted Area R-6002, and the Gamecock B, C, and D MOAs.

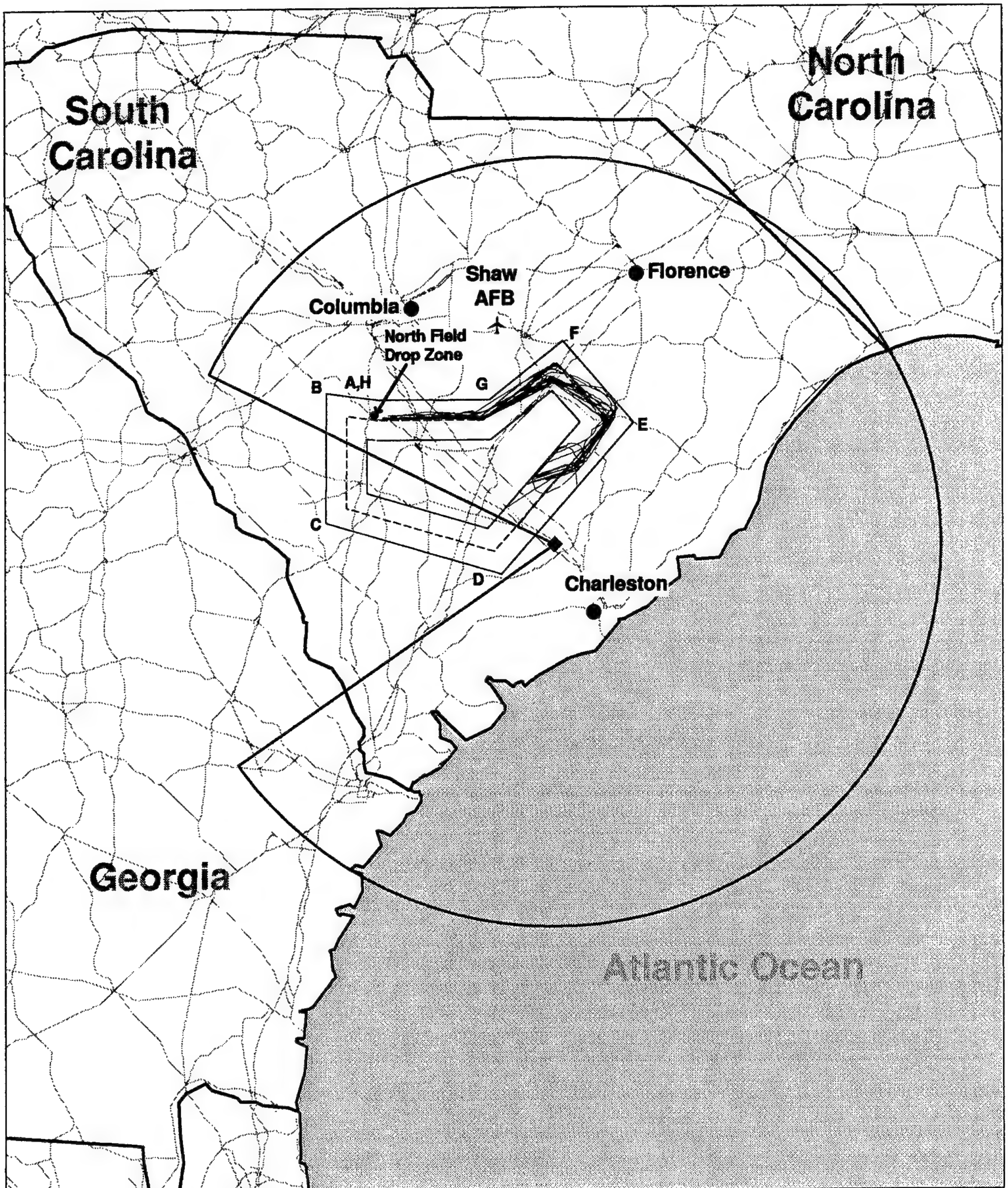
3.4 MTR Flight Track Dispersion

3.4.1 IR-035 and IR-036 Flight Track Dispersion

Flight operations of the C-17 were observed on IR-035 and IR-036. These operations originated from Charleston AFB and used both routes for similar types of training. The training included low-altitude terrain navigation followed by tactical entry into the North Field Drop Zone, where cargo drops and landings are practiced.

The gate analysis method allowed an examination of the C-17 aircraft tracks associated with IR-035 and IR-036. Figure 3-2 showed both of these airspaces indicating the region where they are coincident; IR-035 segments overlap most of the northern segments of IR-036. The altitude limits and route widths are nearly identical throughout this region. Similar horizontal and vertical flight track dispersion patterns were observed on both airspaces at a number of measurement points throughout the coincident airspace region. Analysis is provided for IR-036 and for the coincident sections of IR-035 and IR-036.

Figure 3-6 shows the C-17 radar ground tracks on IR-036 obtained using the gate analysis procedure. The direction of the flight operations is counterclockwise, and the tracks are shown only for the region of airspace covered by the radar. The track colors indicate different altitude stratifications. It is evident from this picture alone that the tracks have various lateral dispersion characteristics throughout the airspace. An expanded view of the IR-036 radar ground tracks is shown in Figure 3-7. The C-17s enter the airspace near alternate entry point D, south of gate 1. Through gate 1 the distribution of tracks is narrow, and most operations are along a single track. As the C-17s turn left at point E, the flight tracks disperse and remain widely distributed through gates 2, 3, and 4. In this region, pilots use many different references to practice low-altitude navigation. The only constraint is that the aircraft remain within the route boundaries. Flight operations throughout the remainder of IR-036, through gates 5 to 7, are associated with tactical entry into North Field. Here the radar tracks are distributed along a single track which is



Scale

0 20 40

Miles

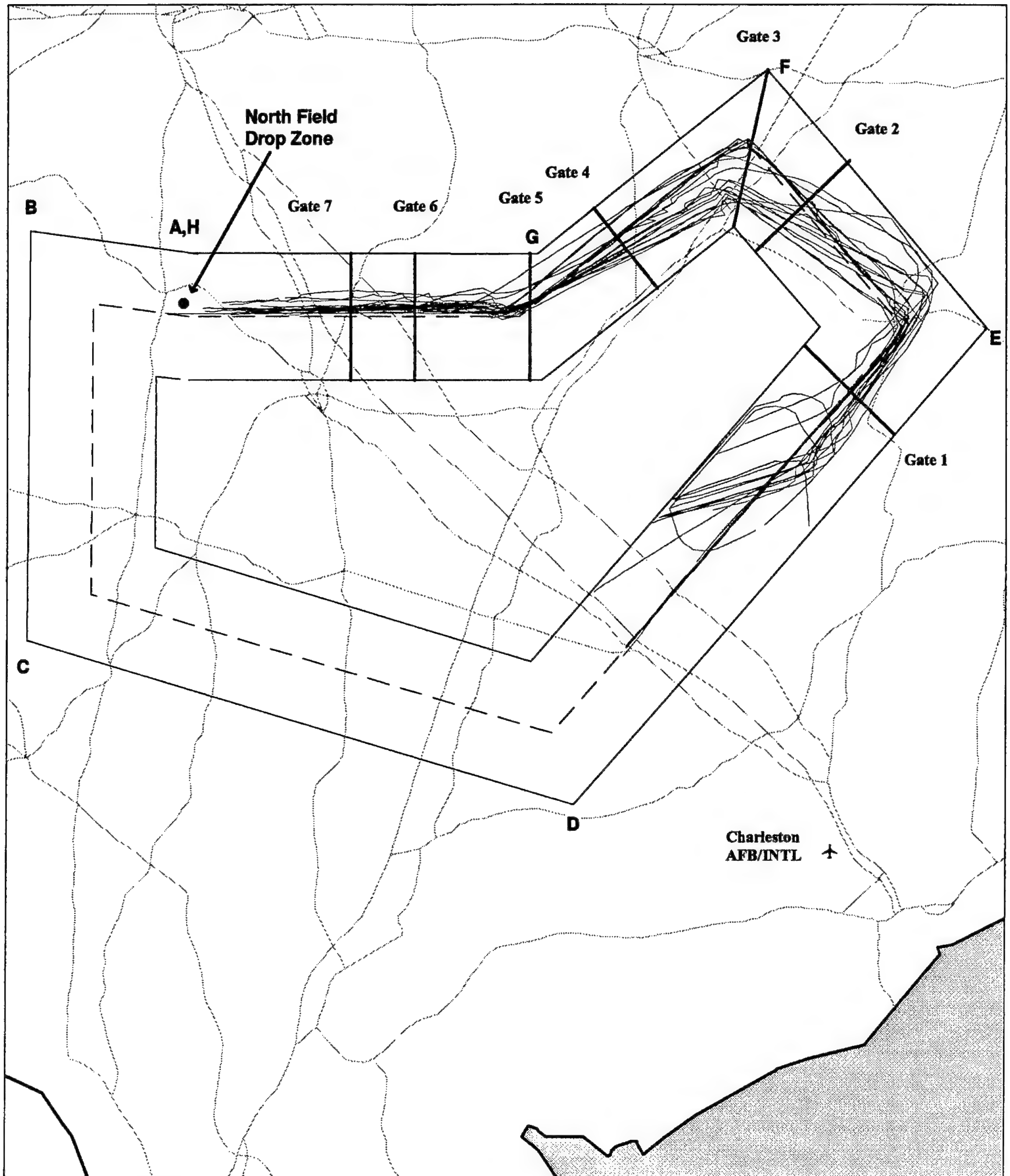
N

Legend

- MTR Boundary
- MTR Centerline
- 500 to 2000 Feet MSL
- 2000 to 5000 Feet MSL
- Radar Position
- Radar Coverage

Figure 3-6

IR-036 Radar Tracks



Scale

0 7.5 13

Miles

N

Legend

MTR Boundary
MTR Centerline
500 to 2000 Feet MSL
2000 to 5000 Feet MSL
Analysis Gate

Figure 3-7

IR-036 Radar Tracks with Analysis Gates

located approximately one nautical mile north of the IR-036 route centerline. Using this track, aircraft enter North Field which is also north of the centerline and oriented in a northeast to southwest direction. Due to radar coverage, the tracks terminate prior to the North Field location; otherwise, C-17s would be observed turning to the southwest when initiating an approach to the airfield.

The system of seven gates mentioned above corresponds to analysis points along the route. Each gate is oriented normal (perpendicular) to the direction of flight and spans the width of the route. The tracks shown are for those C-17s that penetrated gates 1 through 7, confirming flight operations through a large section of IR-036 airspace (at least 100 nautical miles). Table 3-1 provides a listing of the measured flight parameters for the C-17 aircraft that penetrated gate 1 including the date, time, airspeed, altitude, beacon number, and track number. The altitudes and airspeeds are consistent with expected values.

Table 3-1

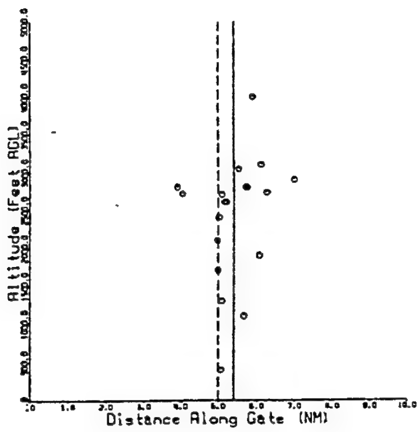
Measured Flight Parameters for C-17 Aircraft
Through IR-036 Gate 1

Date	Time Local	Airspeed (KTS)	Altitude Ft, MSL	Beacon Number	Track Number
12 October	11:10:49	347	2,100	4340	0649
18 October	10:53:03	315	2,400	4332	0339
27 October	10:35:56	289	4,000	1044	0012
27 October	10:48:33	286	3,100	4375	0426
27 October	11:28:49	265	3,100	5525	0457
31 October	10:00:15	315	400	4332	0744
31 October	10:10:17	316	1,300	4332	0054
31 October	11:17:12	292	2,700	5552	0726
2 November	09:35:59	252	2,800	4371	0193
2 November	10:24:40	292	2,800	4325	0250
2 November	10:44:18	283	2,600	4205	0072
2 November	11:03:44	298	2,700	4370	0251
2 November	11:31:23	273	2,600	4232	0877
21 November	09:27:03	242	2,900	4237	0923
21 November	10:13:19	227	1,100	5303	0949
30 November	13:15:12	258	1,700	4212	0883
1 December	11:16:59	273	1,900	5306	0808
1 December	11:56:15	267	2,800	2565	0234
5 December	10:14:51	233	2,700	4355	0703

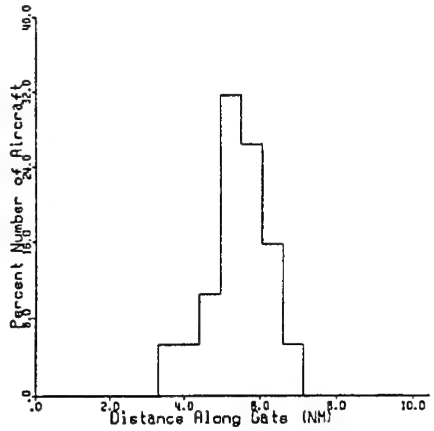
Horizontal and vertical flight track dispersion statistics were computed at each gate. The distance across each gate ranges from zero nautical miles, starting from the left (inside) boundary of IR-036, to the value of the route width in nautical miles, at the right (outside) boundary. While all the figures in this section are presented in statute miles, the dispersion statistics are calculated using nautical miles.

Figure 3-8 presents a scatter plot, horizontal dispersion histogram, and vertical dispersion histogram for gates 1 through 7. The scatter plots show the penetration points (altitude and lateral position) for C-17 aircraft crossing the specified gate. Two vertical lines are shown in these figures; the dotted line represents the location of the route centerline, and the solid line indicates the value of the mean of the horizontal (lateral) flight track distribution. The horizontal dispersion histograms show the percent number of aircraft occurring in approximately one-half-nautical-mile-wide bins along each gate. The abscissa for the scatter plots and horizontal dispersion histograms reflect the length of the gate, and hence the route width. The vertical dispersion histograms show the percent number of aircraft occurring in altitude bins of approximately 250 feet. The gate number and horizontal standard deviation are noted in each of the figure subtitles, a through g.

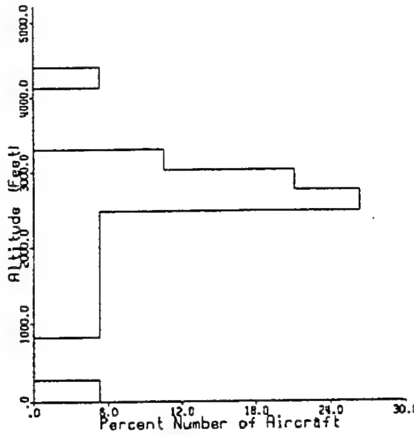
Examining the scatter plots, the horizontal dispersion indicates that the C-17s are flying a specific narrow track through gate 1, more dispersed tracks through gates 2 to 4, and then along a progressively tighter single track through gates 5 to 7 as they line up for cargo delivery or landing at North Field. These trends are also shown in the horizontal dispersion histograms which help to visualize where individual tracks are located. The vertical histograms reflect the measured drop in altitude as the C-17s travel through gates 1 to 7. Table 3-2 lists the statistics at each gate, including the ratio of the standard deviation divided by the route width for the measurements of dispersed flight tracks. Previous studies[2,4,5] of flight track dispersion have defined this ratio to be 0.17 – based on acoustic measurements performed on seven low-altitude routes. The current study examines this ratio for additional routes, including narrow width and asymmetric (i.e., the centerline is not located at the geometric center of the route corridor) cases.



(i) Scatter Plot.

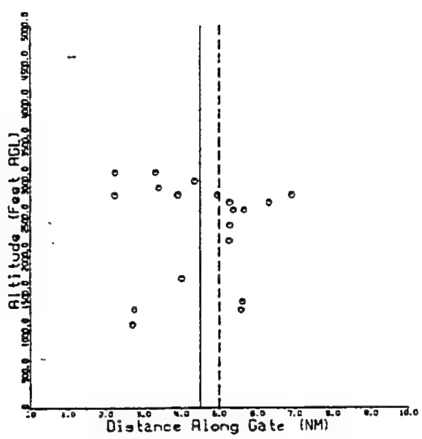


(ii) Horizontal Dispersion.

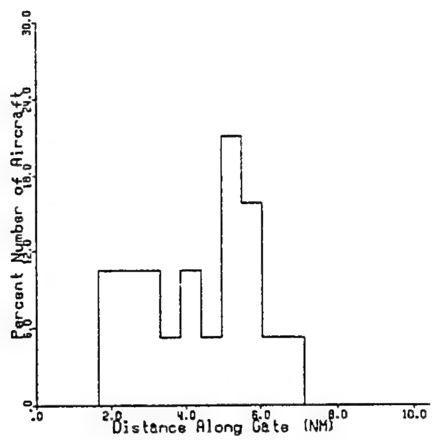


(iii) Vertical Dispersion.

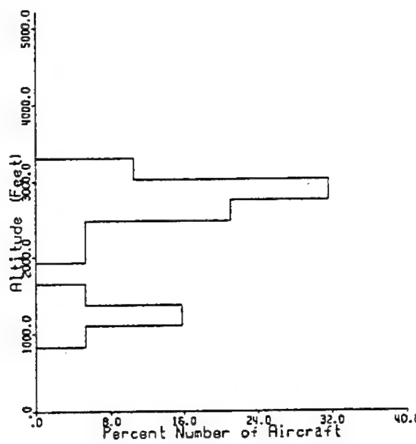
a. Gate 1: Horizontal Standard Deviation = 0.73 nm.



(i) Scatter Plot.

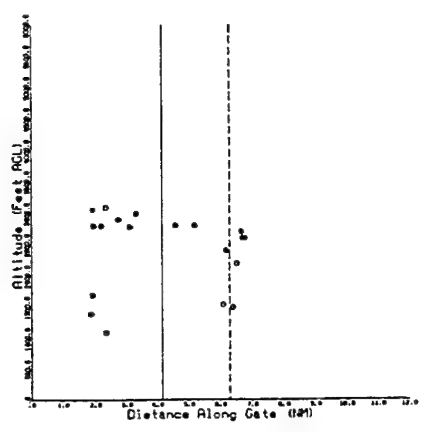


(ii) Horizontal Dispersion.

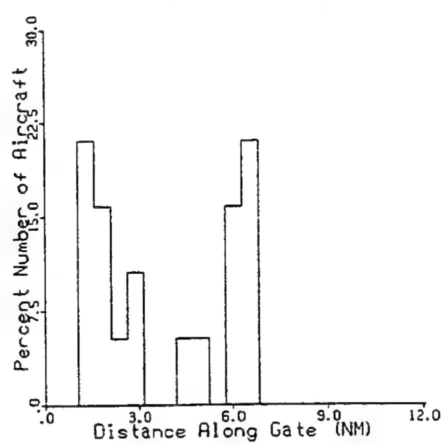


(iii) Vertical Dispersion.

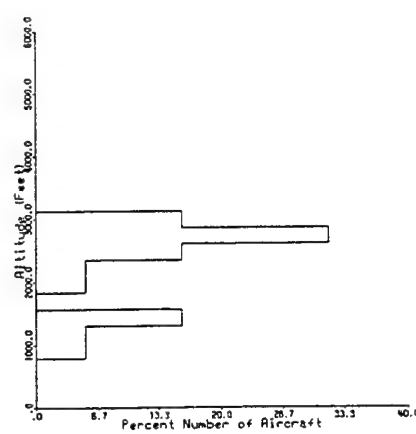
b. Gate 2: Horizontal Standard Deviation = 1.40 nm.



(i) Scatter Plot.



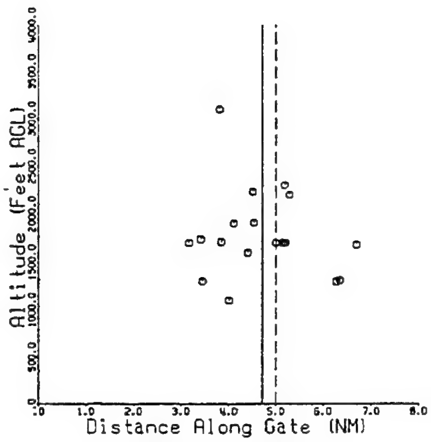
(ii) Horizontal Dispersion.



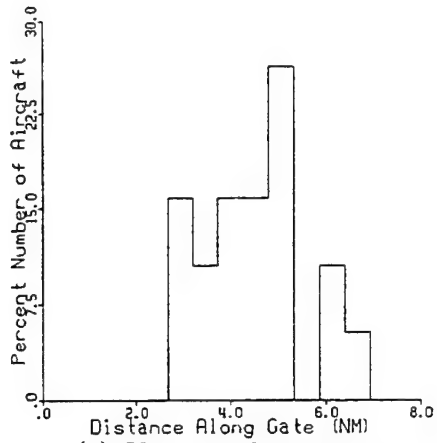
(iii) Vertical Dispersion.

c. Gate 3: Horizontal Standard Deviation = 2.02 nm.

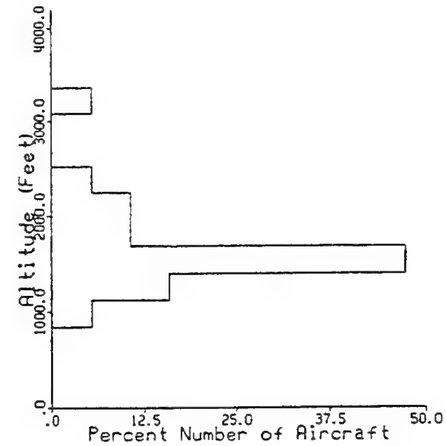
Figure 3-8. C-17 Aircraft Dispersion on IR-036.



(i) Scatter Plot.

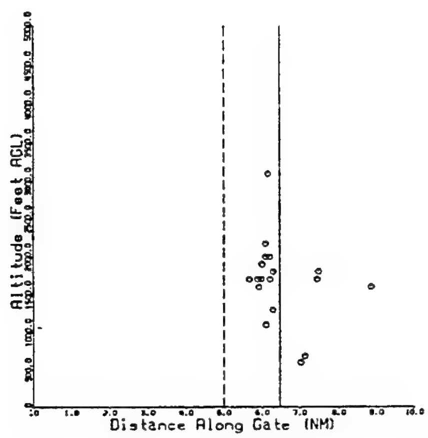


(ii) Horizontal Dispersion.

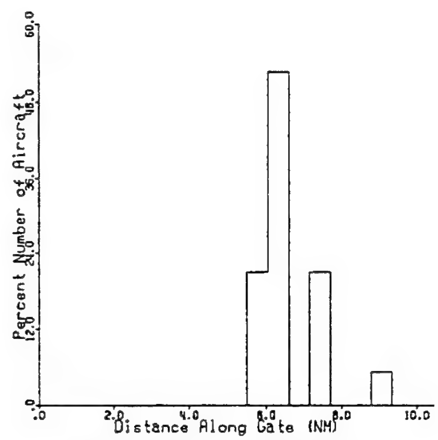


(iii) Vertical Dispersion.

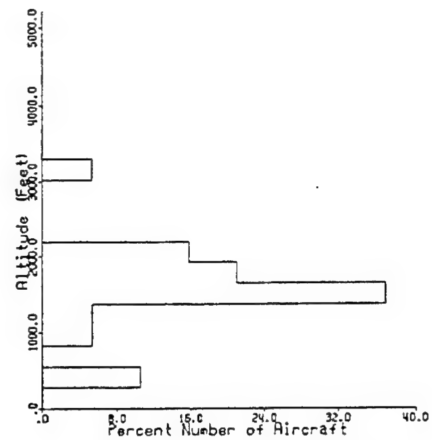
d. Gate 4: Horizontal Standard Deviation = 1.02 nm.



(i) Scatter Plot.

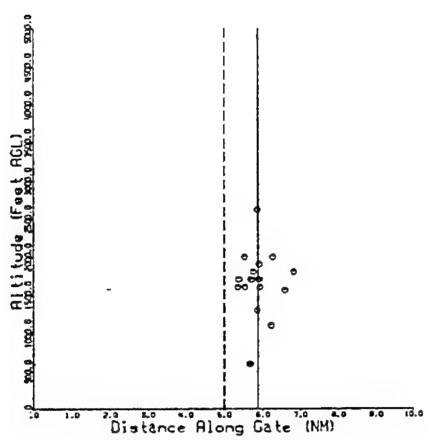


(ii) Horizontal Dispersion.

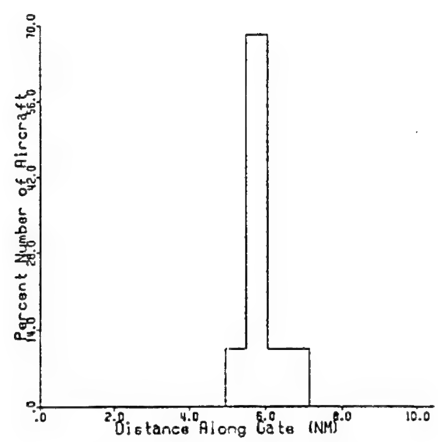


(iii) Vertical Dispersion.

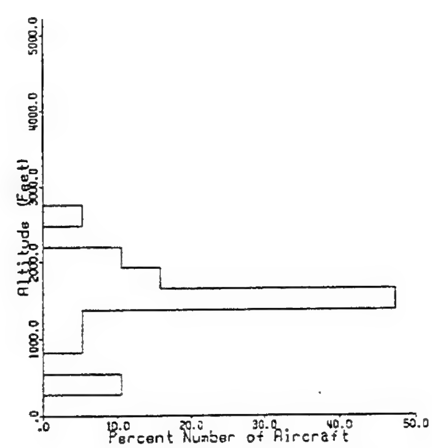
e. Gate 5: Horizontal Standard Deviation = 0.78 nm.



(i) Scatter Plot.



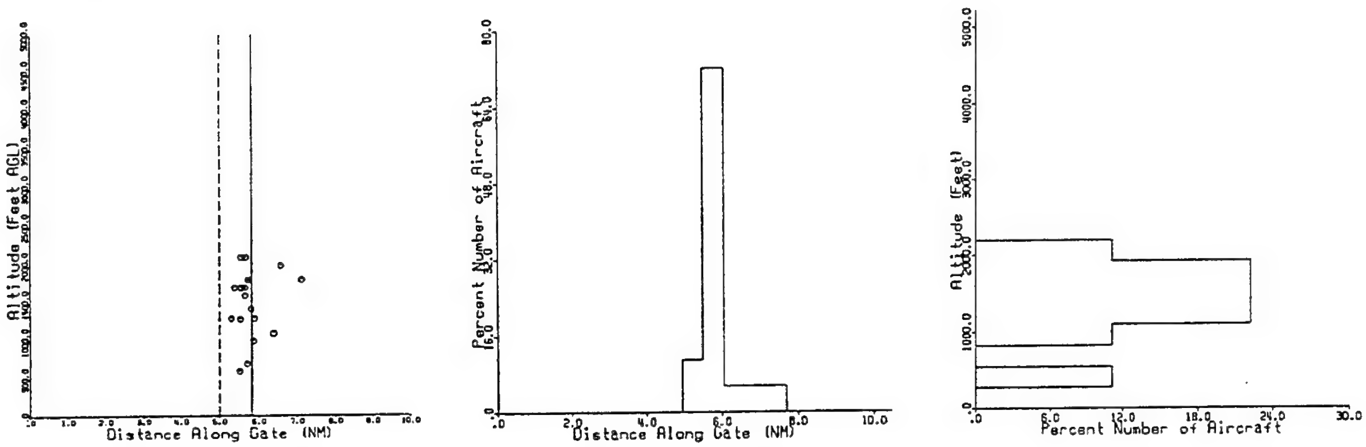
(ii) Horizontal Dispersion.



(iii) Vertical Dispersion.

f. Gate 6: Horizontal Standard Deviation = 0.38 nm.

Figure 3-8 (Continued).



(i) Scatter Plot.

(ii) Horizontal Dispersion.

(iii) Vertical Dispersion.

g. Gate 7: Horizontal Standard Deviation = 0.45 nm.

Figure 3-8 (Concluded).

Table 3-2

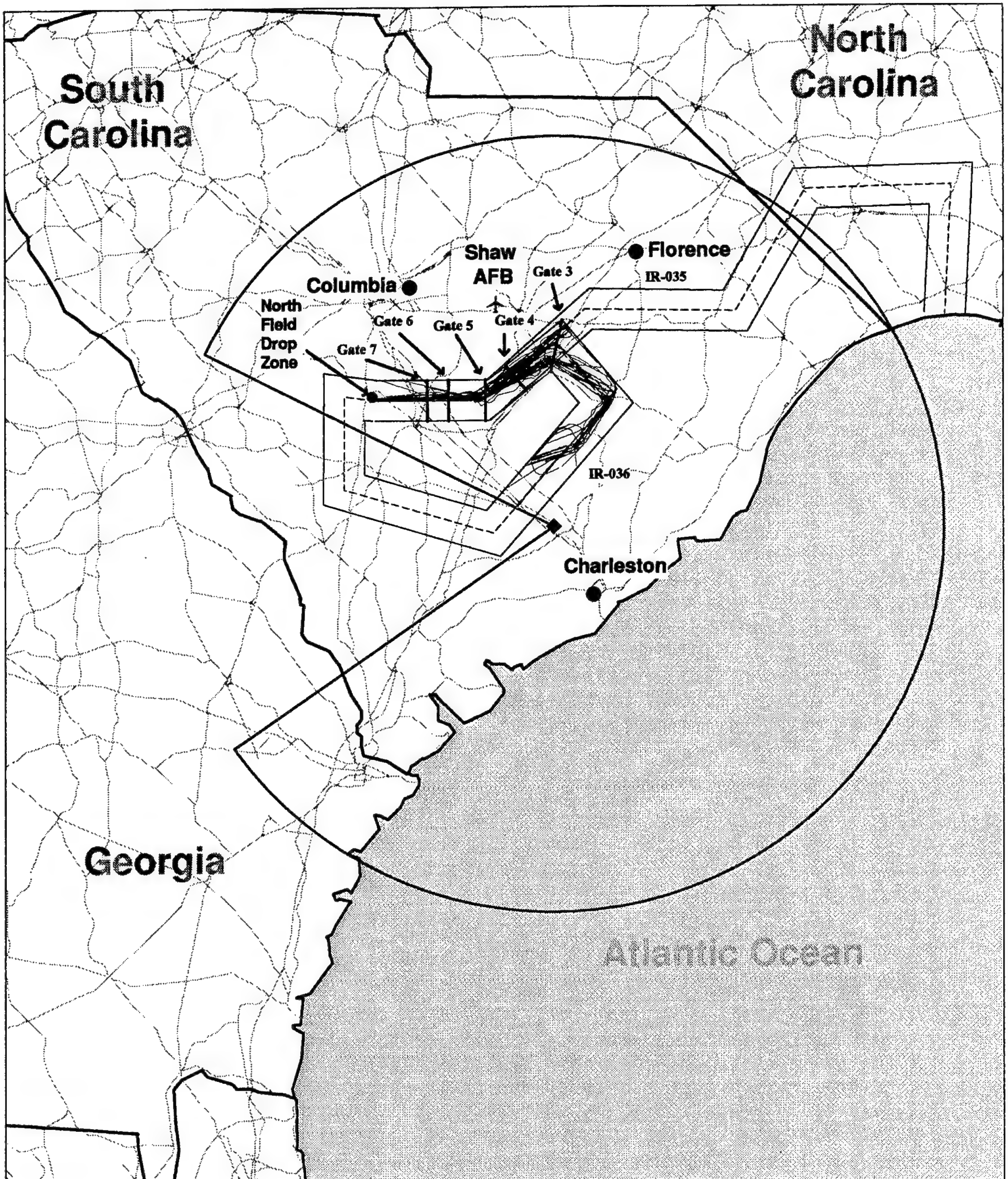
Gate Statistics for C-17 Operations on IR-036

Analysis Gate	Flight Track Horizontal Dispersion in Nautical Miles				Flight Track Vertical Dispersion in Feet MSL			
	Mean	**Std. Dev.**	**Route Width**	**Ratio***	**Mean**	**Std. Dev.**	**IR-036 Floor**	**IR-036 Ceiling**
1	5.40	0.73	10.00		2,404	826	300	4,000
2	4.48	1.40	10.00	0.14	2,382	672	300	4,000
3	4.15	2.02	12.61	0.16	2,409	634	300	3,000
4	4.71	1.02	8.00**	0.13	1,782	450	300	3,000
5	6.48	0.78	10.00		1,681	537	300	3,000
6	5.87	0.38	10.00		1,609	467	300	3,000
7	5.81	0.45	10.00		1,500	443	300	3,000

* Ratio = Standard Deviation divided by Route Width for dispersed flight operations.
** Asymmetric route segment.

Since the C-17 operations occurring on IR-035 are similar to those on IR-036, it was worthwhile to reanalyze the flight operations in the coincident airspace region to obtain a higher data yield. Figure 3-9 shows IR-035 and IR-036 along with the radar ground tracks through gates 3 to 7. These are the same gates used in the previous analysis; however, the requirement for this analysis was that tracks had to penetrate gates 3 through 7. Previously for analysis of IR-036, the requirement was that tracks had to penetrate all gates (gates 1 through 7) which meant that no IR-035 traffic would be included. The ground tracks in this figure are similar to those in Figure 3-6; however, an additional stream of tracks is observed along IR-035 at the north end of gate 3 (tracks are only shown within the IR-036 boundary).

An analysis was performed on the C-17 flight operations in the coincident airspace, similar to that for IR-036, above. Table 3-3 lists the C-17 flight parameters through gate 3. Each record includes: the date, time, airspeed, altitude, beacon number, and flight track number. Figure 3-10 provides scatter plots, horizontal dispersion histograms, and vertical dispersion histograms for C-17 aircraft operations at gates 3 through 7 on IR-035 and IR-036. The dispersion measurements for these five gates are very similar to those previously measured for IR-036, with the exception of gate 3. In this case, the stream of tracks coming in from IR-035 causes the horizontal dispersion to increase from a standard deviation of 2.02 to 3.31 nautical miles. For the coincident airspace, both the radar ground tracks and the scatter plot for gate 3 show three separate groups of flight tracks, whereas only two groups were present for the operations solely on IR-036.



Scale

0 20 40

Miles

N

Legend

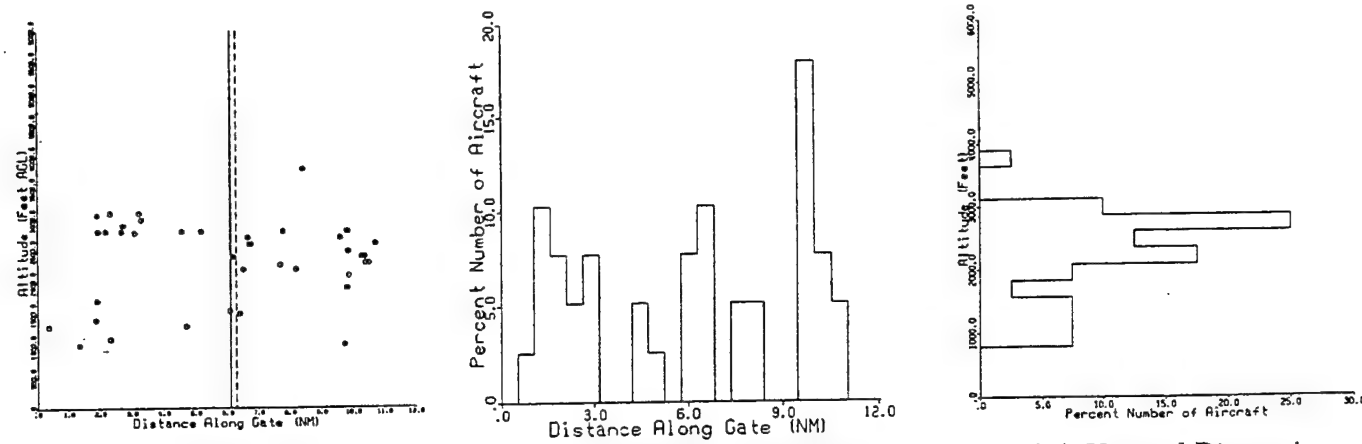
MTR Boundary
MTR Centerline
500 to 2000 Feet MSL
2000 to 5000 Feet MSL
Analysis Gate
Radar Position
Radar Coverage

Figure 3-9
IR-035 and IR-036 Radar Tracks with Analysis Gates

Table 3-3

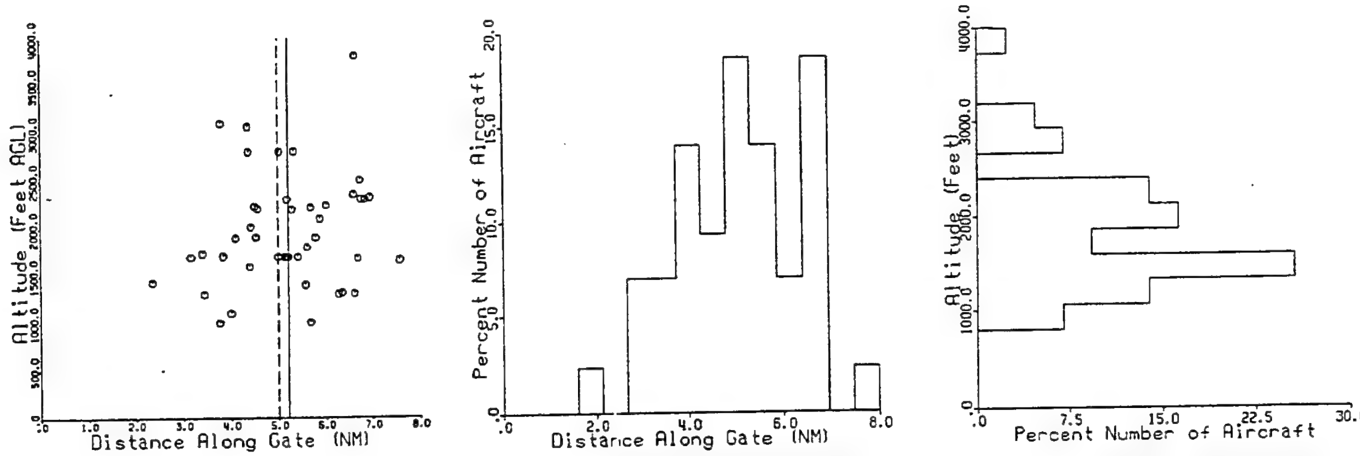
Measured Flight Parameters for C-17 Aircraft
Through IR-035 and IR-036 Gate 3

Date	Time Local	Airspeed (KTS)	Altitude Ft, MSL	Beacon Number	Track Number
12 October	11:14:49	370	2,200	4340	0649
13 October	11:34:17	265	2,800	2722	0468
18 October	10:57:39	323	2,400	4332	0339
19 October	14:27:31	207	2,300	5513	0208
19 October	14:33:56	221	2,200	5513	0208
19 October	14:48:58	201	2,300	5513	0208
19 October	14:52:10	214	2,200	5513	0208
20 October	10:16:56	258	1,900	4215	0452
20 October	12:16:57	316	2,500	3020	0093
27 October	10:42:20	236	3,000	1044	0012
27 October	11:35:37	211	3,100	5525	0457
27 October	10:42:32	232	3,100	1000	0941
27 October	10:14:05	223	2,100	4342	0286
27 October	10:53:21	259	3,100	4375	0426
31 October	10:04:27	353	1,500	4332	0744
31 October	11:22:24	290	2,700	5552	0726
31 October	09:26:34	308	2,600	1002	1008
31 October	10:04:39	335	1,600	4332	0054
2 November	09:44:35	207	2,800	4371	0193
2 November	11:37:11	251	2,600	4232	0877
2 November	10:03:25	214	2,700	5542	0242
2 November	10:30:28	256	2,800	4325	0250
2 November	11:10:21	220	2,800	4370	0251
2 November	10:50:06	239	2,600	4205	0072
13 November	09:50:03	255	2,800	2672	0458
15 November	02:39:58	203	2,400	5332	0976
15 November	03:06:13	258	1,300	5332	0976
15 November	03:07:25	218	1,300	5332	0976
21 November	09:34:39	201	2,900	4237	0923
21 November	10:19:55	222	1,100	5303	0949
27 November	08:53:59	214	1,000	4256	0612
30 November	13:21:00	247	1,700	4212	0883
1 December	10:00:27	232	2,800	4342	0360
1 December	11:23:23	235	1,400	5306	0808
1 December	10:43:43	229	1,000	5306	0809
1 December	12:02:02	235	2,800	2565	0234
1 December	12:33:30	212	2,800	4301	0926
5 December	10:22:03	222	2,700	4355	0703



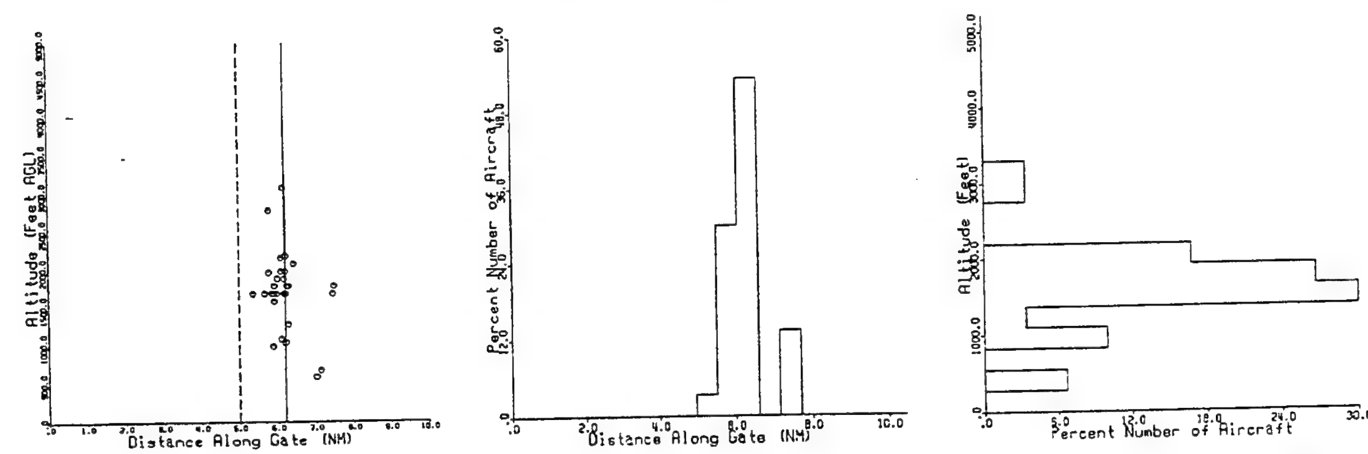
(i) Scatter Plot. (ii) Horizontal Dispersion. (iii) Vertical Dispersion.

a. Gate 3: Horizontal Standard Deviation = 3.31 nm.



(i) Scatter Plot. (ii) Horizontal Dispersion. (iii) Vertical Dispersion.

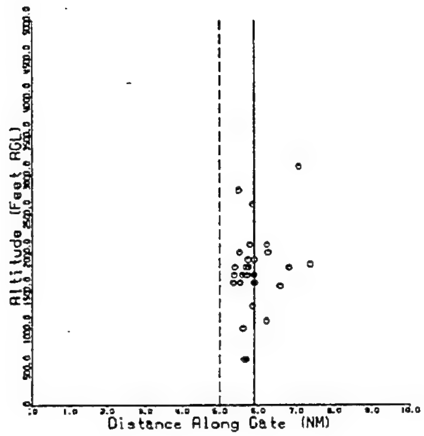
b. Gate 4: Horizontal Standard Deviation = 1.20 nm.



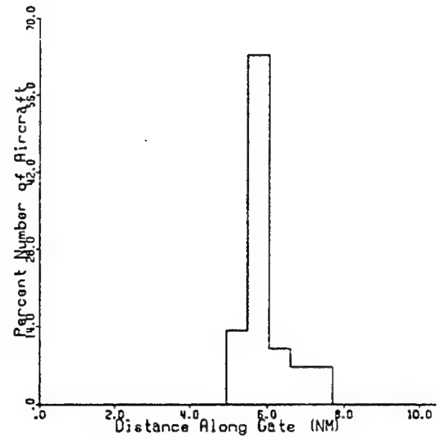
(i) Scatter Plot. (ii) Horizontal Dispersion. (iii) Vertical Dispersion.

c. Gate 5: Horizontal Standard Deviation = 0.48 nm.

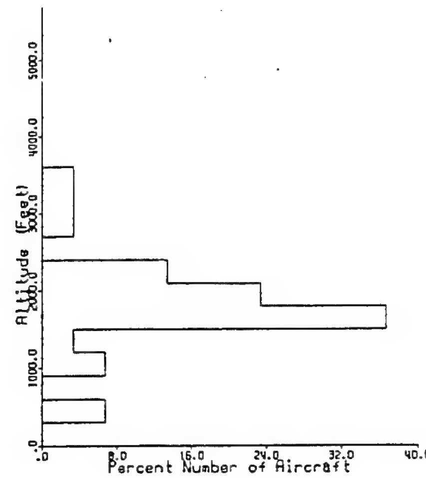
Figure 3-10. C-17 Aircraft Dispersion on IR-035 and IR-036.



(i) Scatter Plot.

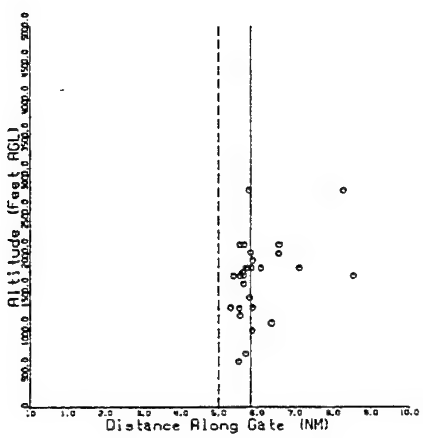


(ii) Horizontal Dispersion.

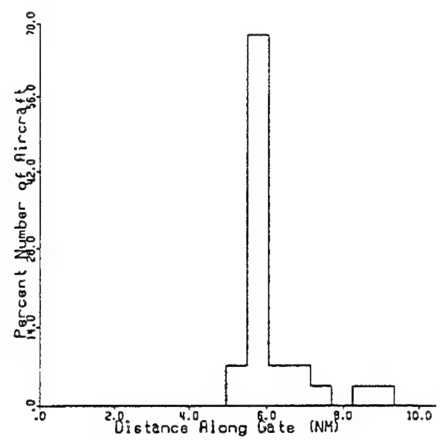


(iii) Vertical Dispersion.

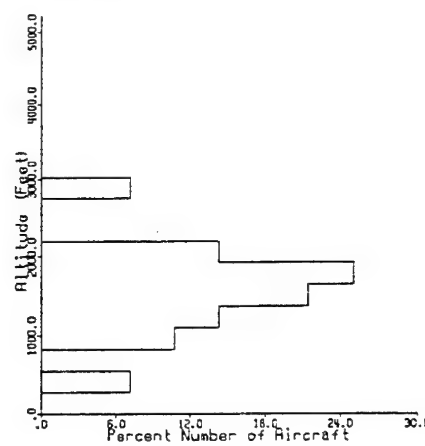
d. Gate 6: Horizontal Standard Deviation = 0.49 nm.



(i) Scatter Plot.



(ii) Horizontal Dispersion.



(iii) Vertical Dispersion.

e. Gate 7: Horizontal Standard Deviation = 0.41 nm.

Figure 3-10 (Concluded).

Table 3-4 provides the statistics for gates 3 through 7, including the ratio of the standard deviation divided by the route width for the measurements of dispersed flight tracks.

Table 3-4

Gate Statistics for C-17 Operations on IR-035 and IR-036 Coincident Airspace

Analysis Gate	**Flight Track Horizontal Dispersion in Nautical Miles**				**Flight Track Vertical Dispersion in Feet MSL**			
	Mean	**Std. Dev**	**Route Width**	**Ratio***	**Mean**	**Std. Dev.**	**IR-035/ IR-036 Floor**	**IR-035/ IR-036 Ceiling**
3	6.11	3.31	12.61	0.26	2,353	663	300	3,000
4	5.21	1.20	8.00**	0.15	1,973	598	300	3,000
5	6.21	0.48	10.00		1,736	519	300	3,000
6	5.91	0.49	10.00		1,744	528	300	3,000
7	5.84	0.41	10.00		1,672	509	300	3,000

* Ratio = Standard Deviation divided by Route Width for dispersed flight operations.
** Asymmetric route segment.

3.4.2 VR-1041 Flight Track Dispersion

Low-altitude, high-speed flight operations were observed on VR-1041, as shown in Figure 3-11. In addition to use by Navy F/A-18 aircraft, this route is used by Air Force tactical jets and transports including: F-16s, F-15s, F-4s, C-17s, and C-130s. The direction of travel on this route is counter-clockwise from point A to point I.

Although this route is almost entirely within the radar coverage, the radar ground tracks are discontinuous throughout the northern three segments. One reason may have been that the radar tracking was obstructed at the beginning of these segments, causing the radar to temporarily lose sight of the aircraft. Under these circumstances, the radar may have assigned a new flight track number to the aircraft. As mentioned in Section 3.3, the radar data processing program uses the flight track number to group data associated with a single flight track. In this case, two or more flight track numbers may have been assigned to a single aircraft flying through the route. An attempt to manually regroup flight track information was unsuccessful due in part to the large size of the raw radar data files.

Originally it was planned to use the classified Mode 2 aircraft identification codes to obtain a unique identification for each aircraft; however, this information was not being transmitted through the radar data feed in a useable format. Having the Mode 2 identification codes would have made possible the task of grouping together different pieces of the same flight track.

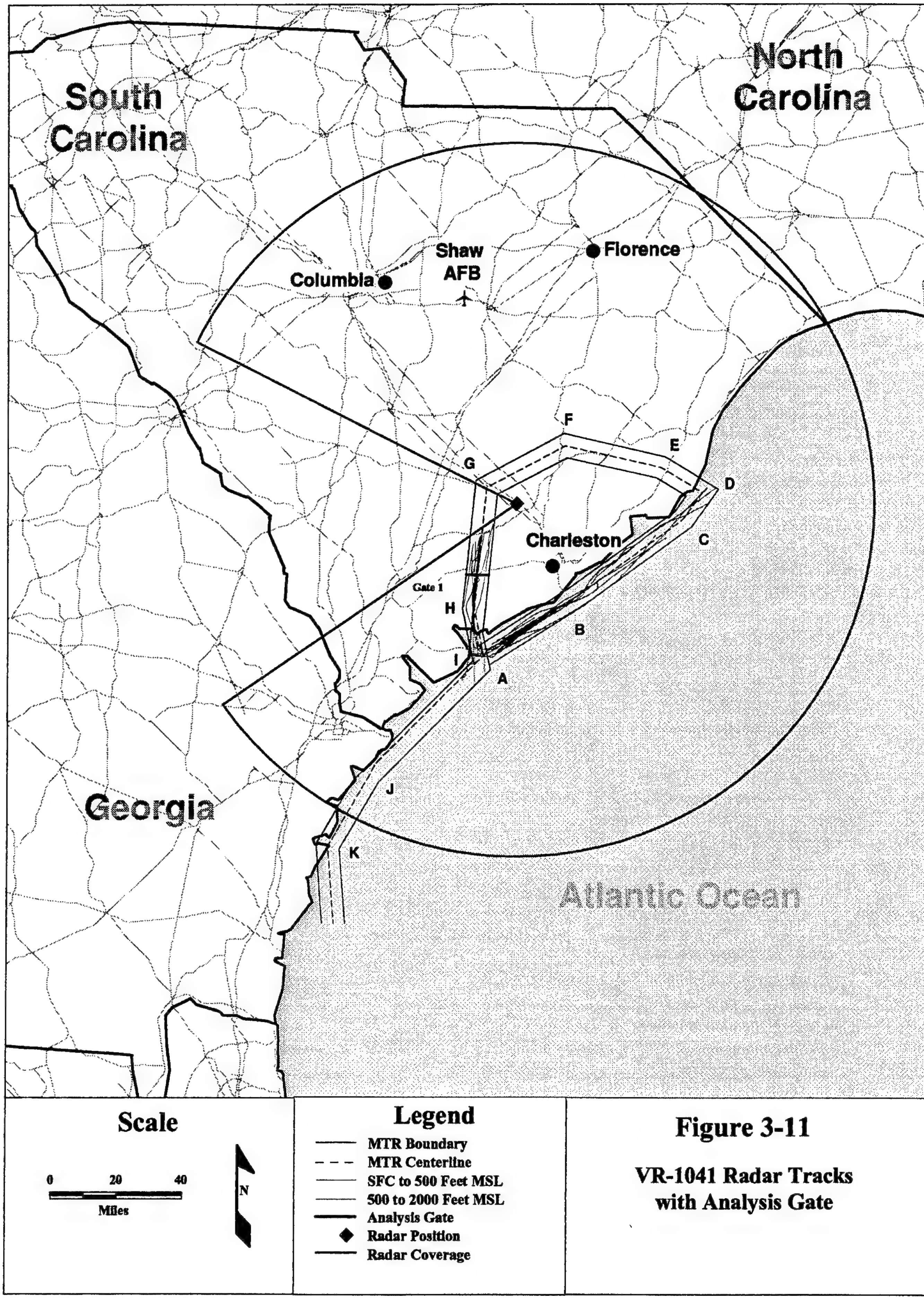


Figure 3-11

VR-1041 Radar Tracks with Analysis Gate

A statistical analysis was performed on the flight tracks occurring between route points G and H, at gate 1 in Figure 3-11. Flight operations occurred from 500 to 1,500 feet MSL, consistent with the published altitude limits for this route segment. Table 3-5 provides a sample of the flight operations penetrating gate 1. These records include operations by high-speed tactical aircraft as well as several transport aircraft. Figure 3-12 shows the measured horizontal and vertical dispersion for the aircraft penetrating gate 1. Again, the dotted line on the scatter plot represents the route centerline, and the solid line indicates the mean of the horizontal flight track distribution. While the number of samples is low, this data confirms that long-range measurements of low-altitude aircraft operations can be obtained using radar. The statistics associated with this sample are presented in Table 3-6.

Table 3-5

Measured Flight Parameters for Aircraft
Through VR-1041 Gate 1

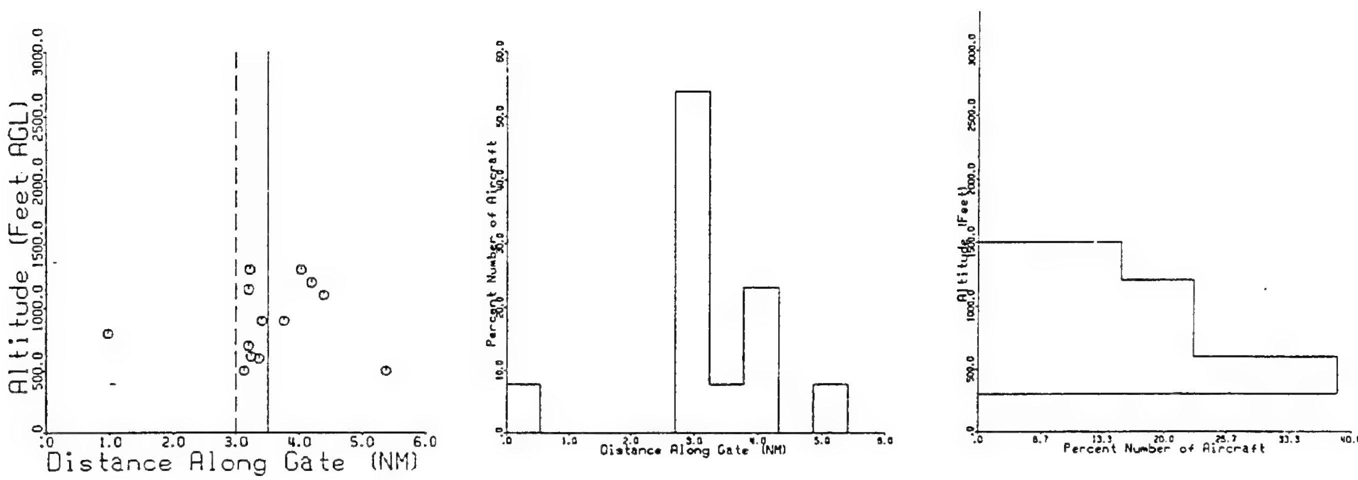
Date	Time Local	Airspeed (KTS)	Altitude Ft, MSL	Beacon Number	Track Number
10 October	14:07:34	499	1,200	1200	0289
13 October	13:00:20	421	500	1200	0092
17 October	11:58:48	408	600	4000	0151
18 October	10:26:31	509	700	4000	0576
18 October	13:56:17	331	900	4000	0094
26 October	11:42:54	498	1,100	4000	0738
06 November	12:08:01	257	900	4000	0151
14 November	10:12:48	251	800	4000	0242
17 November	08:47:38	433	600	4000	0414
22 November	10:04:40	425	500	4000	0039
30 November	13:48:26	326	1,300	4366	0488
30 November	13:48:56	294	1,300	4366	0488
30 November	18:54:35	353	1,200	4366	0488

Table 3-6

Gate Statistics for Aircraft Operations on VR-1041

Analysis Gate	Flight Track Horizontal Dispersion in Nautical Miles				Flight Track Vertical Dispersion in Feet MSL			
	Mean	Std. Dev	Route Width	Ratio*	Mean	Std. Dev.	VR-1041 Floor	VR-1041 Ceiling
1	3.50	1.00	6.00	0.17	889	296	500	1,500

* Ratio = Standard Deviation divided by Route Width for dispersed flight operations.



(i) Scatter Plot. (ii) Horizontal Dispersion. (iii) Vertical Dispersion.

a. Gate 1: Horizontal Standard Deviation = 1.00 nm.

Figure 3-12. Aircraft Dispersion on VR-1041.

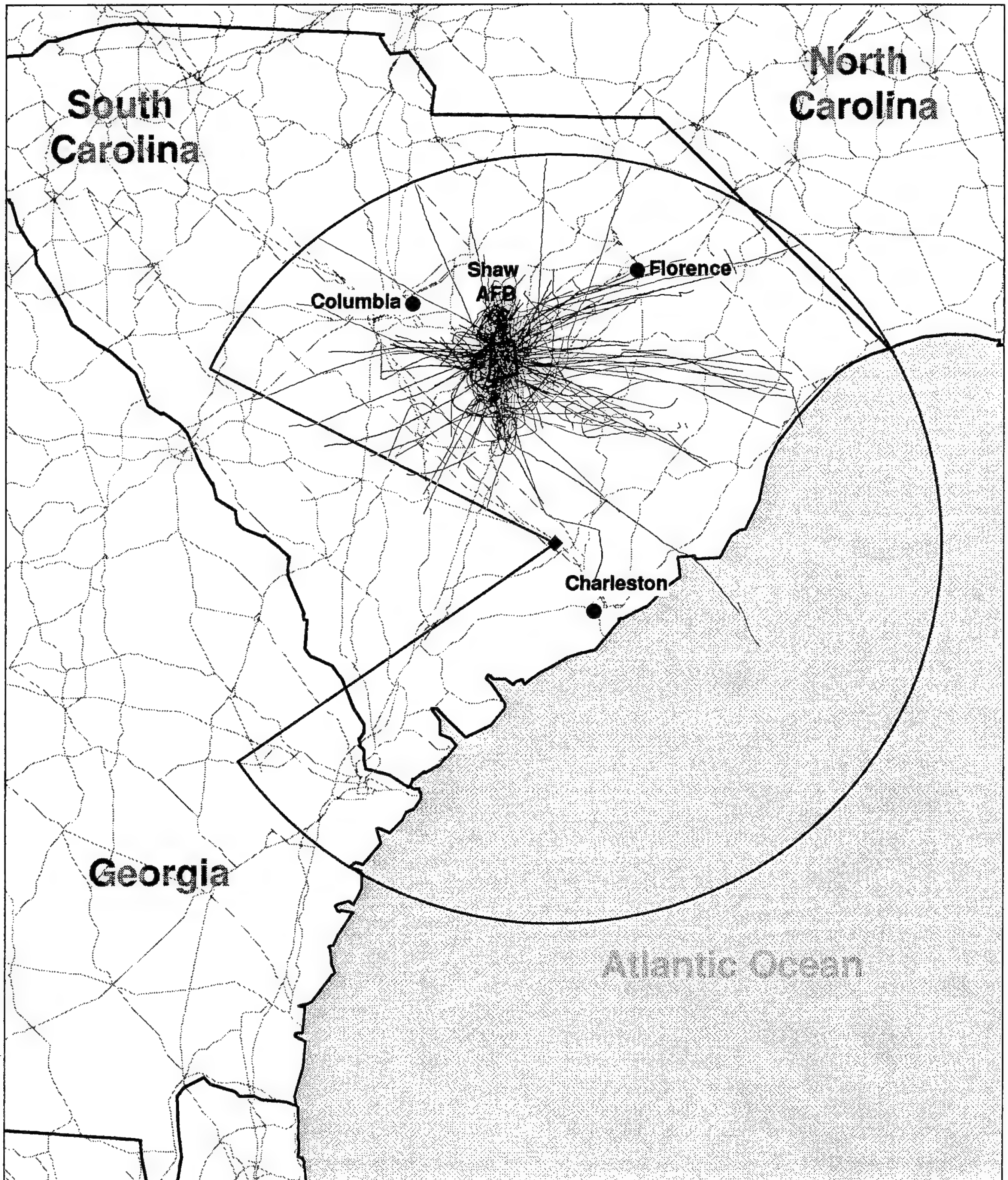
3.5 MOA and Range Analysis Capability

While this study was concerned primarily with MTR flight track dispersion, it is of value to present a qualitative analysis of the radar data collected for Restricted Area R-6002 and the Gamecock B, C, and D MOAs.

Restricted Area R-6002 is a weapons training range used primarily by Air Force tactical aircraft, including F-16s out of Shaw AFB. Figure 3-13 shows Restricted Area R-6002 along with a sample of radar tracks for operations between 1,000 to 13,000 feet MSL. Flight activity on this airspace is cleared from the surface up to 13,000 feet MSL.

Figure 3-14 is an expanded view of Restricted Area R-6002 showing more detailed flight track information. This figure displays flight tracks measured from 1,000 to 5,000 feet MSL. Randomly distributed tracks are seen throughout the airspace at lower altitudes, while a strong circular pattern is observed in the northern half of the airspace. These circular tracks describe bombing patterns where aircraft travel in a counterclockwise direction to reach the target area, which is not shown; however, it is located approximately 2.5 miles southeast of the north-western corner of the airspace. These tracks specifically correspond to low-level "pops" – a maneuver where aircraft approach the target area at approximately 1,500 feet MSL, climb to around 4,000 feet MSL to visualize the target area, drop munitions, and finally turn away from the target area and descend to 1,500 feet MSL. This pattern is normally repeated multiple times during a training period. Also shown in Figure 3-14 are several tracks running from the middle of the southwest quadrant of the airspace toward the northwest corner. These tracks represent strafing runs where the aircraft follow a specific track toward a strafing pit located in the northwest corner of the range.

Other similar training activities include maneuvers such as a high-altitude pop-up where aircraft approach the target at 5,000 to 6,000 feet MSL, climb to 13,000 feet MSL, and then initiate a 30- to 40-degree dive toward the target where the weapon is released. Figure 3-15 shows flight tracks associated with this activity; a circular pattern is indicated for these higher altitude operations, similar to the pattern used for the low-level pops.



Scale

0 20 40
Miles

N

Legend

Restricted Area R-6002
SFC to 500 Feet MSL
500 to 2000 Feet MSL
2000 to 5000 Feet MSL
5000 to 13000 Feet MSL
Radar Position
Radar Coverage

Figure 3-13

R-6002 Radar Tracks: 1000 to 13000 Feet MSL

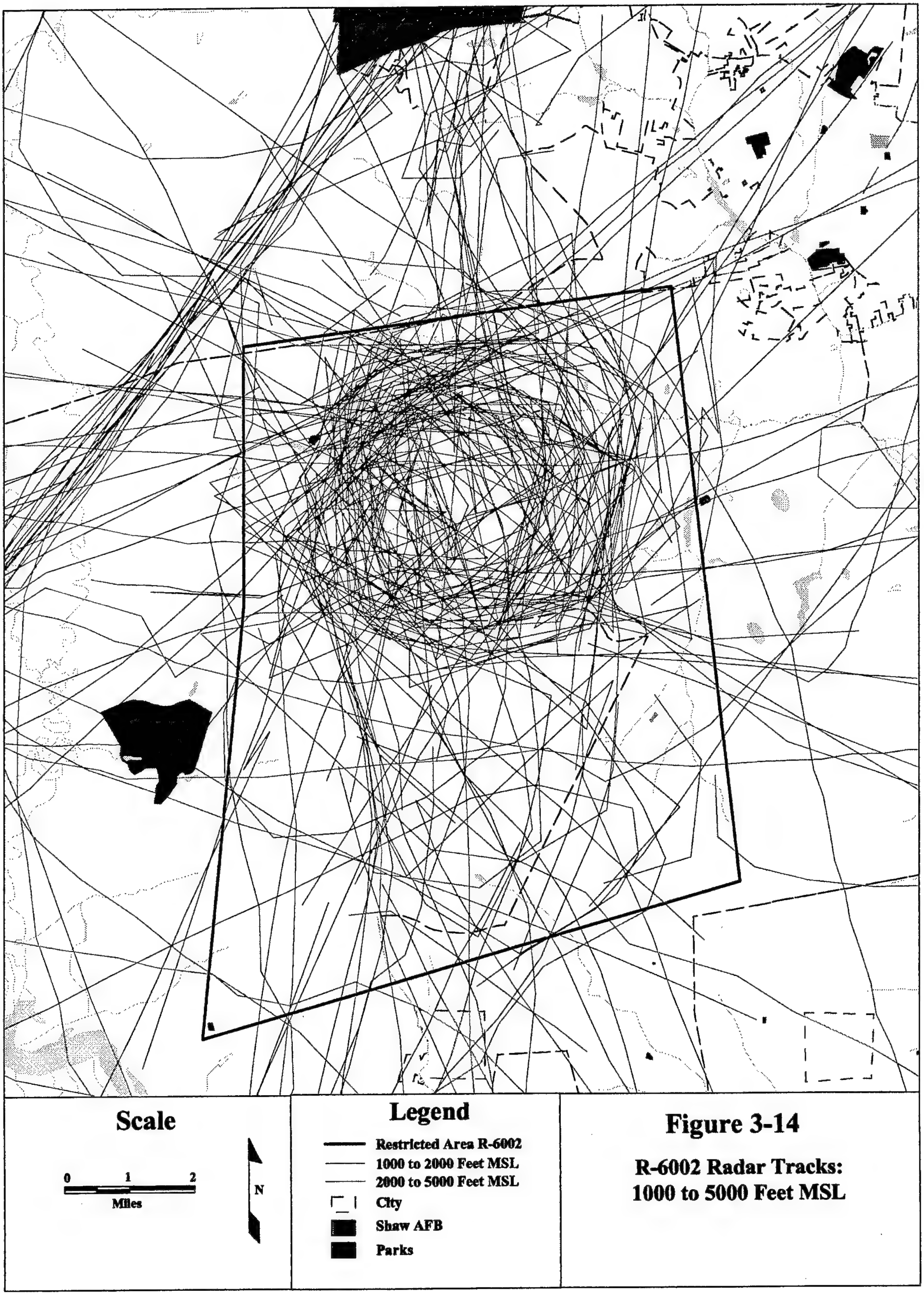


Figure 3-14

R-6002 Radar Tracks: 1000 to 5000 Feet MSL

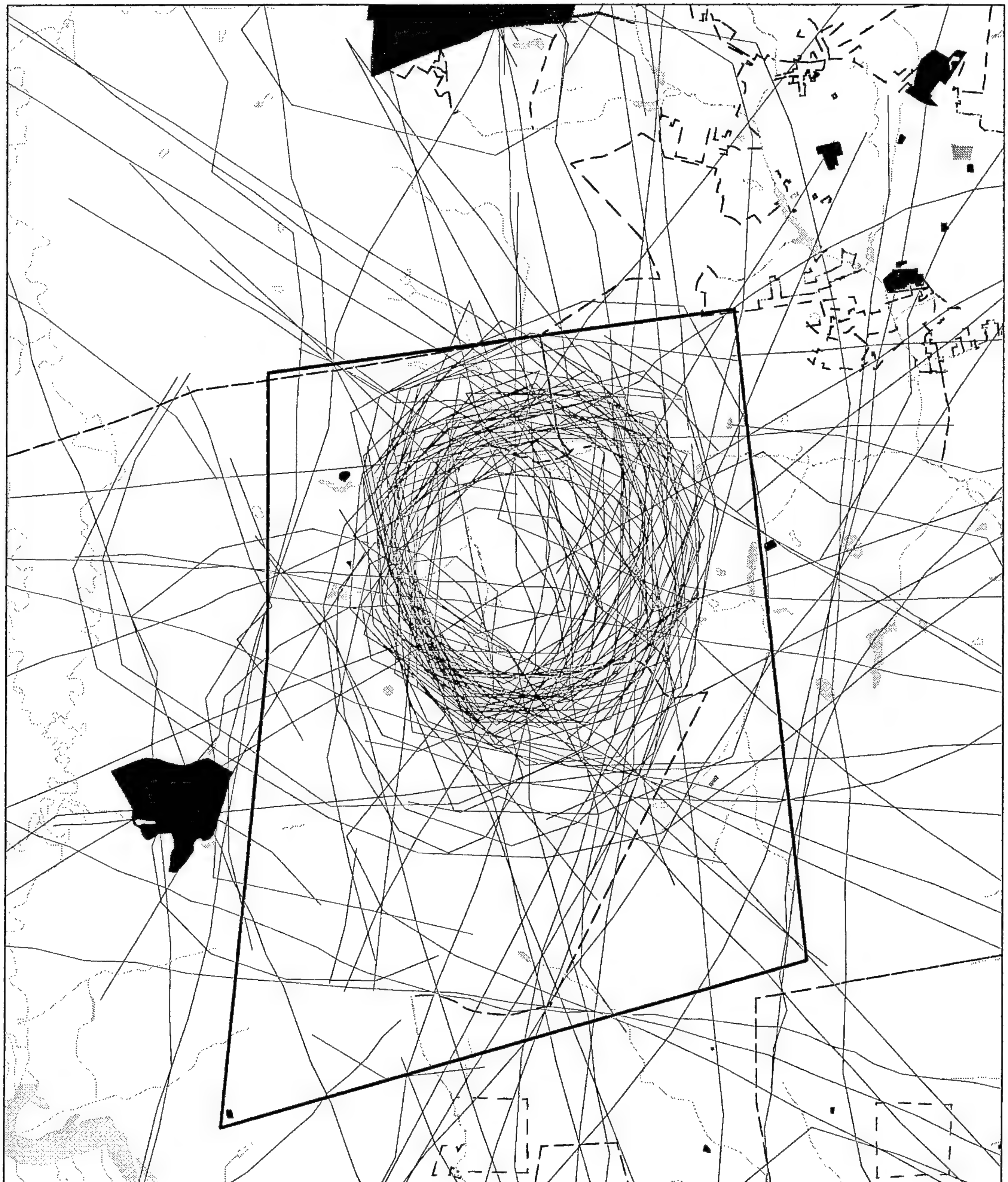


Figure 3-15

R-6002 Radar Tracks: 5000 to 13000 Feet MSL

Figure 3-16 depicts radar tracks for flight operations associated with the Gamecock MOAs. Flight activity in these MOAs typically originate from Shaw AFB, Seymour Johnson AFB, and Charleston AFB. This figure shows a sample of tracks which include aircraft departures from Charleston AFB. As indicated, these aircraft generally climb to above 5,000 feet MSL before entering the Gamecock C MOA through the southern border. Flight operations are observed mostly in the Gamecock C MOA; however, there is some activity in the higher-altitude Gamecock B and D MOAs.

These MOAs are generally used for air-to-air combat training where, for example, an F-16 flight from Shaw AFB will engage a flight of F-15s out of Seymour Johnson AFB. Air-to-ground combat training is also practiced, e.g., an A-10 will mark a target for an F-16 or F-15 flying in trail. The A-10 can either radio the strike coordinates to the trailing aircraft or mark the target with a laser, such that the trailing aircraft can deliver a laser-guided bomb. The circular flight patterns shown in Figure 3-16 are representative of these types of training.

The purpose of this section was to qualitatively analyze radar tracks for the Restricted Area R-6002 and Gamecock MOAs. However, after discussing the data with airspace managers at Shaw AFB, an understanding of the flight operations emerged that would provide specific guidelines for modeling noise in these airspaces. Based on the sample of tracks shown, Restricted Area R-6002 operations could be modeled using three components: (1) randomly distributed tracks for low-altitude operations occurring throughout the airspace; (2) a single defined track representing the circular pop-up pattern; and (3) a single defined track representing the strafing runs. The single track models would need to include appropriate altitude transitions and dispersion characteristics. The flight training occurring in the Gamecock MOAs could be modeled using similar methodology. To accurately model operations in either airspace, the specific aircraft and associated flight parameters should be used; these values are available from radar data.

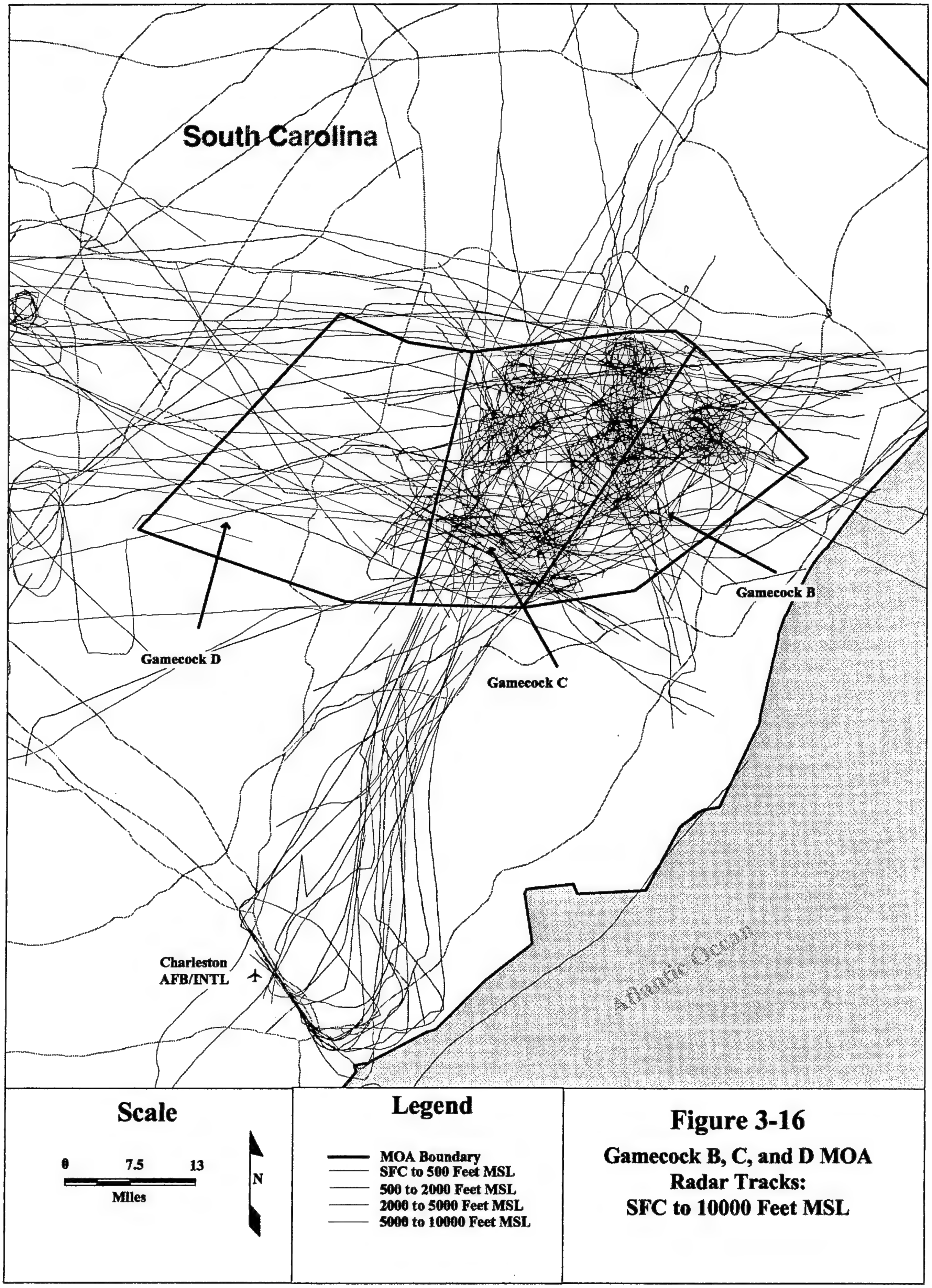


Figure 3-16
Gamecock B, C, and D MOA Radar Tracks: SFC to 10000 Feet MSL

4.0 ACOUSTIC MEASUREMENTS OF AIRCRAFT FLIGHT TRACK DISPERSION ON LOW-ALTITUDE MILITARY TRAINING ROUTES

4.1 Measurement Site Selection

Measurement sites were selected for three MTRs based on the following criteria:

1. Necessity to examine flight profiles on instrument routes (IR).
2. Necessity to examine flight profiles on narrow and asymmetric routes.
3. Areas of relatively flat terrain, to measure activity where altitudes would be lowest and with minimal site-specific constraints.
4. Existence of a reasonably accessible road crossing the route, suitable for deploying noise monitors.
5. High level of flight activity.
6. Differences in aircraft and/or operations were desirable.

Sites meeting these criteria were found along IR-109 in New Mexico, IR-302 in Nevada, and VR-1753 in Virginia. The site associated with VR-1753 was chosen to examine flight operations in a narrow corridor. While no acoustic measurement of an asymmetric route segment was conducted during this part of the study, Section 3.4.1 reports on a measurement obtained, using radar, for the asymmetric route segment F–G associated with the IR-035 and IR-036 coincident airspace.

The acoustic measurements for IR-109, IR-302, and VR-1753 are described in detail in the following sections.

4.1.1 IR-109

Figure 4-1 shows IR-109 as defined in the AP/1B planning guide.[11] This MTR is located primarily in New Mexico, east of Albuquerque. Operations on this route mainly consist of F-111s and EF-111s originating from Cannon Air Force Base. The route centerline is defined by points A through Q along with additional route entry and exit points. Air traffic travels in a clockwise direction from points A through Q. A suitable site for measurement was found along the segment O–P where the route width is 10 nm, 5 nm either side of centerline. The array of noise monitors was

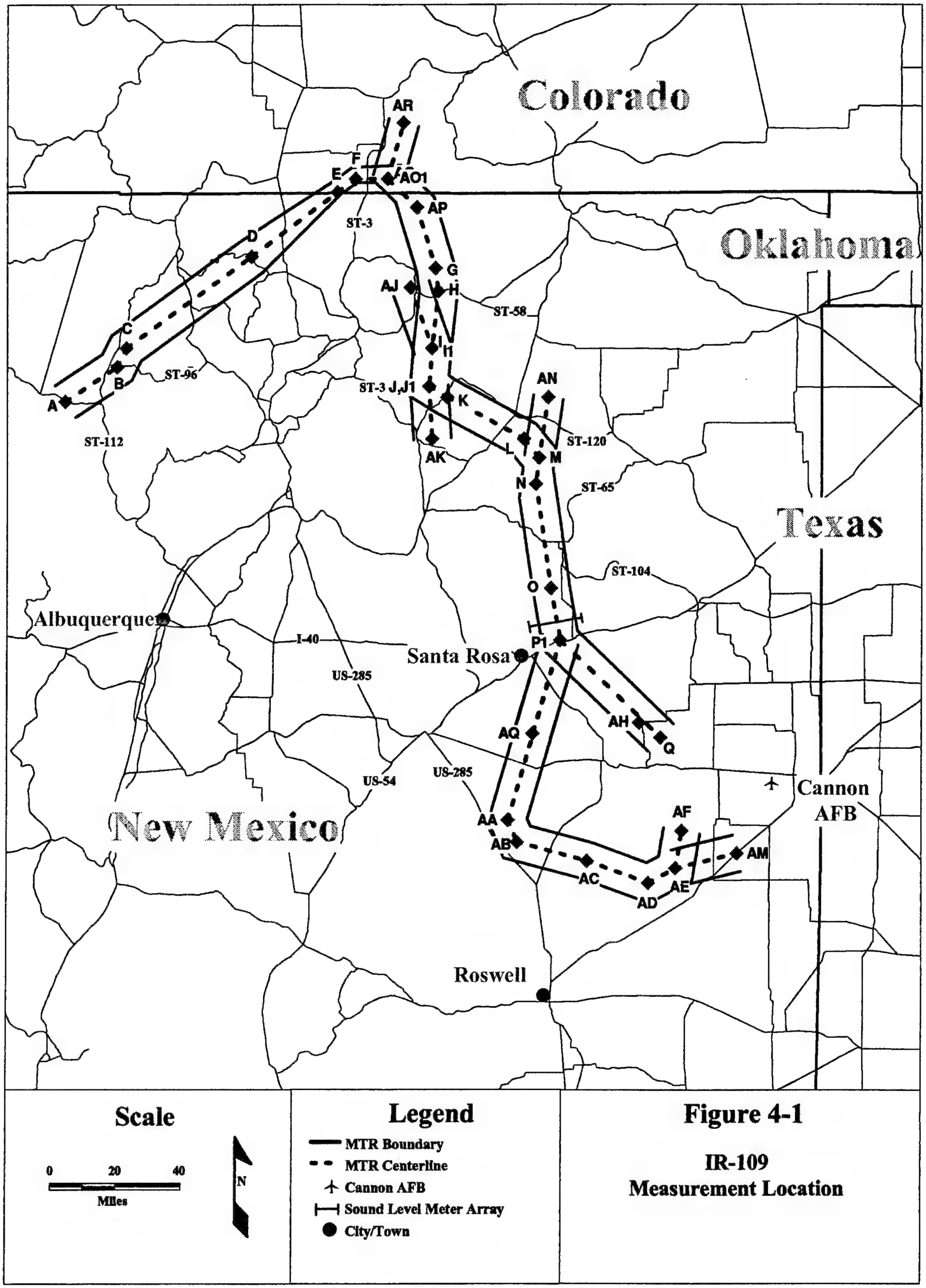


Figure 4-1

IR-109
Measurement Location

located along a gas pipeline access road which is approximately 20 miles northeast of the town of Santa Rosa. Flight operations along this portion of IR-109 are cleared down to 100 feet AGL. The terrain below this section of the route was desert.

An array of 30 noise monitors was installed, spanning the width of the route. The concentration of noise monitors was highest at the center of the route (i.e., one-quarter nautical mile spacing) and progressively lower towards the route boundaries (i.e., one-half to one nautical mile spacing). This interval arrangement maximized the density of noise monitors near the route centerline where most of the air traffic was expected.

Arrangements were made with airspace managers at Cannon AFB to obtain schedule information for IR-109 for the measurement period of 4 May through 1 June 1993.

4.1.2 IR-302

Figure 4-2 depicts IR-302 which is located primarily in southern Idaho and northern Nevada. The route entry point A is approximately 40 miles northeast of the town of Mountain Home, ID. Operations on this route include B-1s, B-52s, F-15Es, and Idaho Air National Guard (ANG) F-4Gs. Air traffic travels in a clockwise direction around the route. The measurement site selected for this route was located along segment J–K, approximately 15 miles south of the town of Jackpot, NV. The route width of segment J–K is 16 nm, 8 nm either side of centerline. The floor of the route is 100 feet AGL between points J and K. The terrain below this section of the route was desert with mountains located nearby to the east.

The measurement site, indicated in Figure 4-2, was on the Harmony Ranch, along a dirt access road running parallel to U.S. Route 93. While the route width at the measurement point is 16 nm, airspace operators associated with the 366th ANG Fighter Wing advised that the majority of flight activity was occurring within 5 nm either side of the centerline. An array of 29 monitors were deployed to cover a 9 nm stretch, 4 nm north and 5 nm south of the centerline. The array could not extend beyond 4 nm to the north of the centerline because the road was impassable. Noise monitors were spaced one-quarter nautical mile apart near the route centerline and progressively farther apart, up to one nautical mile, at the end points of the array.

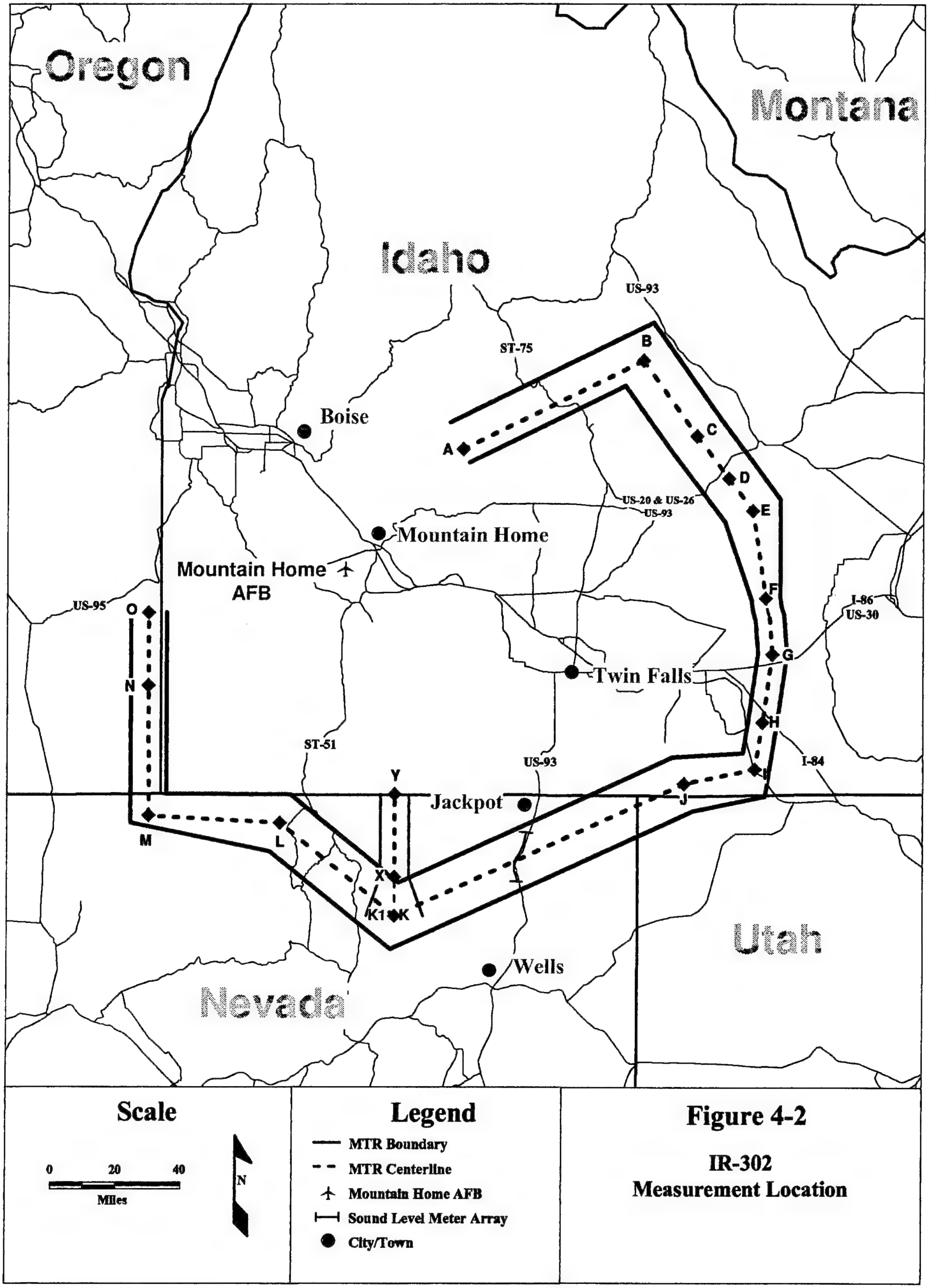


Figure 4-2

IR-302
Measurement Location

IR-302 route segment J–K is coincident with segments of VR-1300 and VR-1304. While a low number of aircraft was anticipated to occur on these two overlapping routes, arrangements were made with the 366th ANG Fighter Wing to obtain schedule information for IR-302, VR-1300, and VR-1304 for the measurement period of 13 October to 14 December 1994.

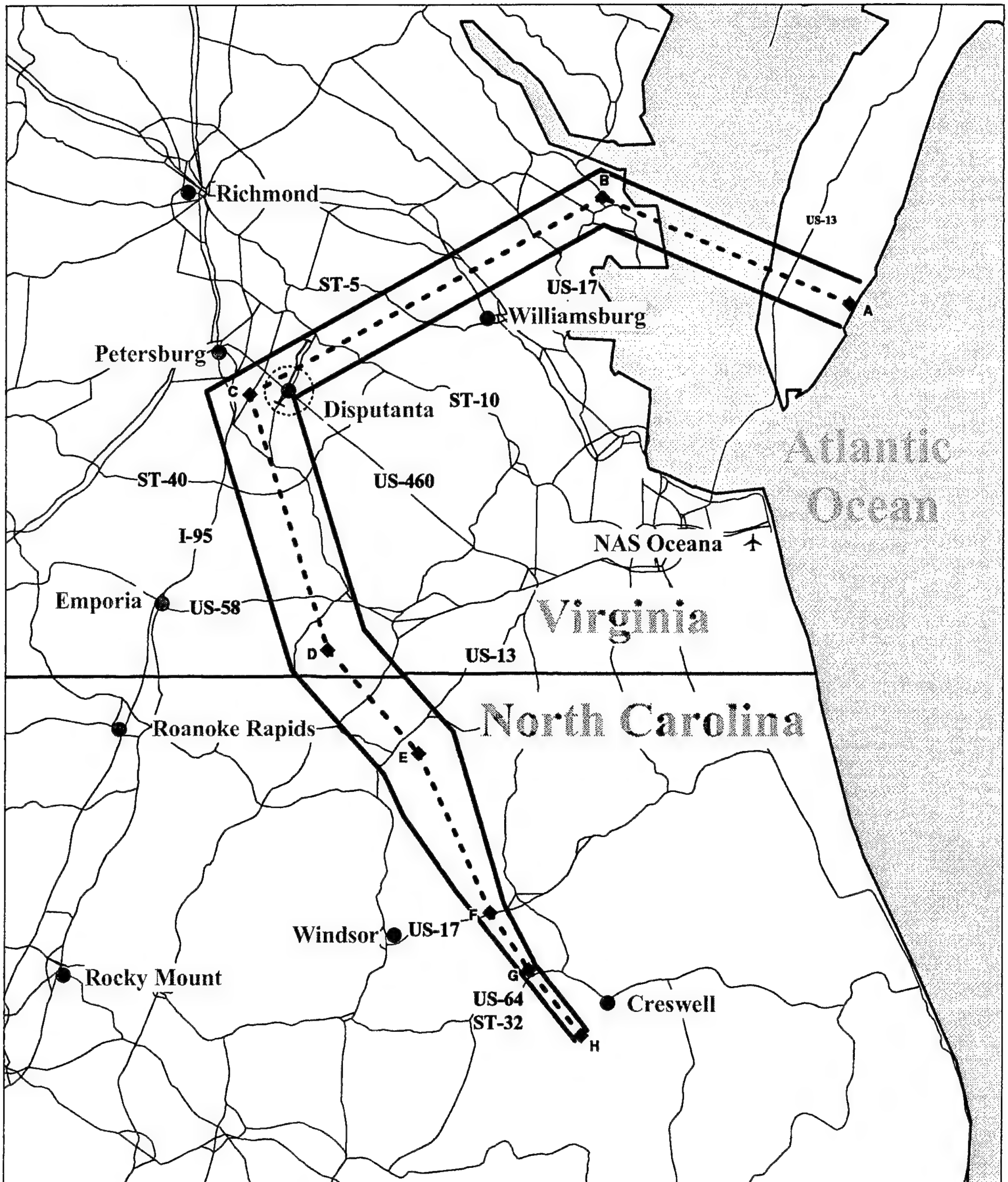
4.1.3 VR-1753

Figure 4-3 shows VR-1753 as defined in the AP/1B planning guide.[11] This MTR is located southeast of Richmond, Virginia. Operations on this route are primarily by F-14s and A-6s, originating from NAS Oceana, but also include F-15s and F-16s. Air traffic travels in a counter-clockwise direction. A measurement site was selected along U.S. Route 156 approximately 15 miles southeast of Petersburg, Virginia. The route segment B–C is 6 nm wide at the measurement site and covers a forested region. The floor of this segment 500 feet AGL.

While the route width is 6 nautical miles at the measurement point, the presence of an avoidance area was expected to restrain flight operations to a corridor with an effective width of about 2 nautical miles. Figure 4-3 shows the circular avoidance area which has a 3-nautical-mile radius centered on the town of Disputanta, Virginia. Expecting flight operations to occur within the 2-nautical-mile-wide area from the northern border of the route to the edge of the avoidance area, the plan was to obtain a dispersion measurement for a narrow MTR.

Noise monitors were chained to telephone poles which provided good visual references for unit location. Ten monitors were placed along Route 156 spanning from 0.5 nautical mile north of the route's northern border to approximately 1 nautical mile south of the centerline. As indicated in Figure 4-3, Route 156 is not oriented normal to the direction of flight operations on the route but is oriented at an angle of approximately 40 degrees to a hypothetical line spanning the width of the route, normal to the direction of flight. To correctly account for the spatial distribution of flight tracks across the route, the coordinates for the monitoring locations were adjusted by Cosine(40°).

Schedule information was obtained from the Air Traffic Control at NAS Oceana during the measurement period of 14 March 1995 to 4 May 1995.



Scale

0 10 20

Miles

N

Legend

MTR Boundary
MTR Centerline
NAS Oceana
Sound Level Meter Array
City/Town
Avoidance Area

Figure 4-3

VR-1753
Measurement Location

4.2 Instrumentation and Field Procedures

4.2.1 Automatic Noise Monitors

Thirty-five automatic noise monitors were available for these measurements. These consisted primarily of Larson-Davis (LD) Model 700 dosimeters along with three Model 820s. Fifteen of the dosimeters were fitted with GenRad 1571-9065 1-inch piezoelectric microphones. The remaining 20 dosimeters were fitted with 3/8-inch Larson-Davis electret microphones. Microphones, along with their windscreens, were placed on 12-inch-square linoleum sheets which were laid on the ground. Each LD-700, together with a battery, was placed in an environmentally sealed container. Figure 4-4 shows a typical monitor site installation. Figure 4-5 shows the LD-700 and its battery inside the container. Field calibration of the monitors was performed using a B&K Type 4230 calibrator.

The LD-700 is a microprocessor-based digital integrating sound level meter. It can be programmed to record interval, exceedance, and history data. Interval data consists of L_{eq} and percentile exceedance levels. Exceedance data consists of records of levels that exceed a preset threshold. History data consists of time histories of measured noise events. The unit can be programmed to record A- or C-weighted levels, slow or fast detector response, and to integrate with 3, 4, or 5 dB/doubling of time tradeoffs, corresponding to L_{eq}, DoD noise dose, and OSHA noise dose. The primary information collected for this project was the exceedance data. The threshold was generally set to 65 dB. It was set higher at sites with significant extraneous noise so as to avoid recording excessive spurious data. The highest threshold used was 70 dB.

The LD-700s have a bi-directional computer interface which can be used to program the unit and to read data from it. A laptop computer was used for this purpose. Software developed for previous MTR measurements[2,4,5] was used to initialize and program the LD-700s, and to read and store data for subsequent analysis. The initialization routine included setting the LD-700's internal clock so that all monitors were time synchronized.

A maximum of 30 monitors were installed on a given MTR. The remaining five monitors were used as spares when installed units failed. The monitors were placed along rural roads and chained to convenient anchors for security (power line towers, telephone poles, or trees).

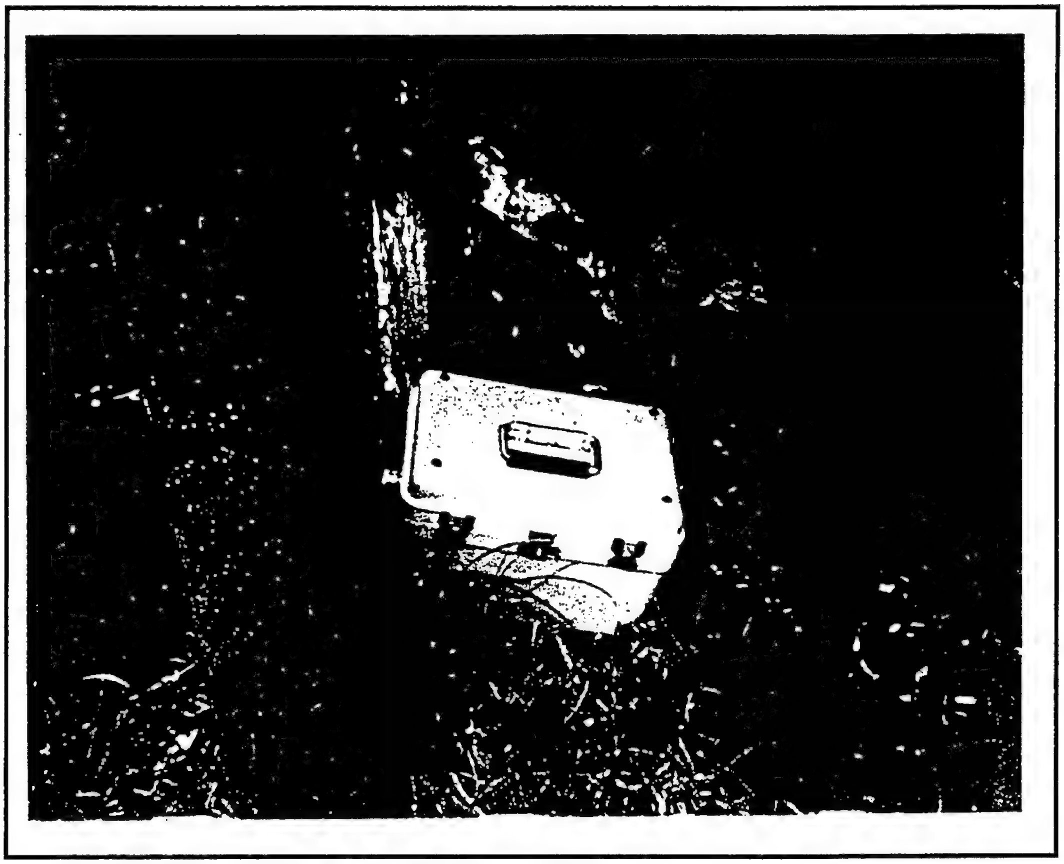


Figure 4-4. Typical Monitor Installation.

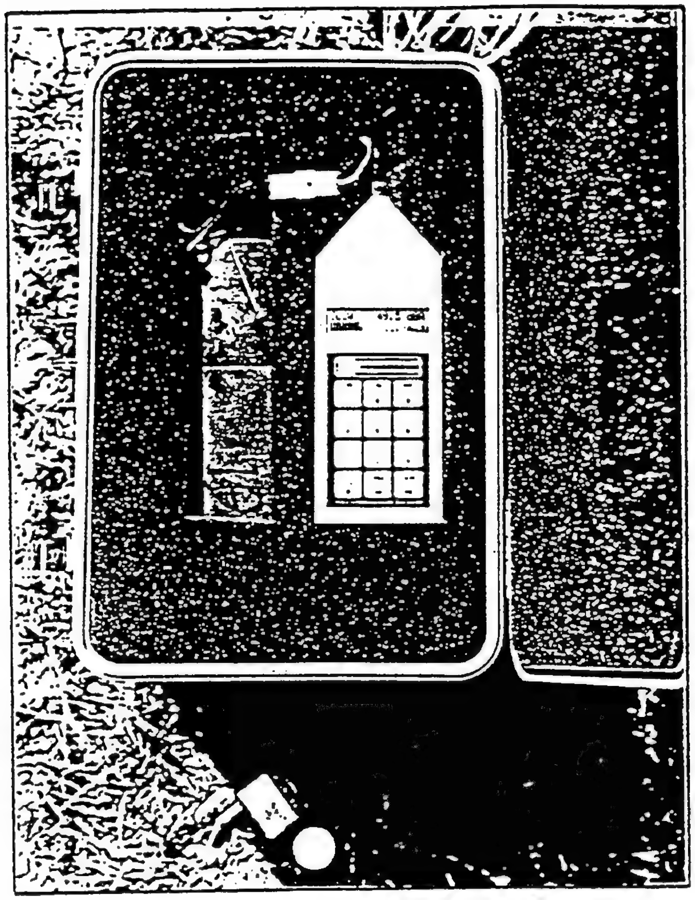


Figure 4-5. LD-700 and Battery Inside Environmental Case.

The monitors were placed at optimum intervals across the MTRs such that as many as possible would record an overflight. Therefore, if a particular monitor was not operating when an overflight occurred, several other monitors would capture the event. This aided in identifying overflights from the monitor data. Other considerations in determining monitor separation intervals were the width of the route to be covered and the availability of convenient anchor sites.

4.2.2 Field Service Procedures

Following initial installation, the monitors were checked once per day during the measurement period. A site visit consisted of checking the meter's operational status, battery power, free memory, and the number of recorded exceedances. A calibration procedure was conducted to ensure the system was operating within tolerance. If the unit had acquired a large number of data records, all data were then downloaded to a portable computer for permanent retention and subsequent analysis. Records of these operations, along with the time and date, were noted in a site log.

Depending on the noise environment in which the monitor was located, data were downloaded every day or at least every third day. Occasionally the memory in a unit would be full due to a lost windscreen, livestock or rodent interference, or other unpredictable events which would leave the unit inoperable until the next site visit.

If a particular unit was discovered to be dysfunctional, the unit was pulled from the field and replaced with a spare. The rechargeable batteries usually lasted 7 to 10 days before replacement was necessary.

4.3 Data Analysis Procedures

Following completion of the field programs, data from the monitors were collated and correlated with the route schedule and field log. This information was compiled into an inventory of events from which statistical and other conclusions could be drawn. Reduction of the data consisted of the following steps:

1. A composite list of scheduled and observed flights was compiled.
2. All data files from the monitors were printed out. Figure 4-6 shows part of a typical exceedance report from a monitor located under the centerline of IR-109. Aircraft flyover events and calibration records are indicated.
3. Beginning with known (observed) events, the general pattern of exceedance records was established. This included identifying typical maximum levels, durations, and the correlation between different monitors.
4. Next, all monitor data/files were examined for exceedance events which corresponded to aircraft overflights. These events were correlated with the schedule information.
5. Finally, a listing of all recorded events was compiled. This list included the exceedance information from each monitor site which recorded the event.

A single-ship overflight generated exceedance records as follows: the monitor closest to being directly under the aircraft would show a maximum level in excess of 90 dBA and a duration of 15 to 25 seconds, while adjacent and more distant monitors would show corresponding lower levels of shorter duration. A two-ship, line-abreast formation would exhibit two peaks in noise level 0.5 to 1 mile apart. An ideal four-ship box formation would exhibit four distinct maximum levels, corresponding to two line-abreast records about 30 seconds apart.

Data reduction consisted of extracting these patterns from monitor exceedance reports. Most exceedances recorded did not correspond to aircraft, but to road traffic noise, farm equipment, rain storms, livestock, and other animals. Aircraft exceedances were easily discerned from the other exceedance sources. An aircraft overflight would be recorded by at least three monitors simultaneously with the characteristics discussed previously. Other noise sources rarely triggered more than one monitor at a time.

Once all aircraft exceedances were gathered and correlated, the location of each aircraft was assumed to be coincident with the monitor showing the maximum noise level. The remaining analyses consisted of statistical descriptions of overflight locations and levels at each site.

	Cnt	LVL	SEL	Lmax	Lpk	Date	Time	Dur		Pk	Ov
cal	1	93.5	96.5	93.5	97.0	2 MAY	11:54:03	0:32	m:s	0	0
	2	66.0	68.0	68.5	84.5	2 MAY	11:54:54	0:01	m:s	0	0
	3	66.5	70.0	70.5	102.0	2 MAY	11:55:00	0:02	m:s	0	0
	4	69.0	77.0	76.5	104.5	2 MAY	11:55:08	0:05	m:s	0	0
	5	66.0	70.5	68.5	82.0	2 MAY	16:07:11	0:02	m:s	0	0
	6	66.0	69.5	68.0	82.0	2 MAY	16:32:48	0:02	m:s	0	0
*	7	67.5	82.0	71.5	88.5	2 MAY	16:37:02	0:27	m:s	0	0
	8	64.0	66.0	65.5	77.0	3 MAY	7:00:40	0:01	m:s	0	0
	9	63.5	64.0	65.5	75.5	3 MAY	7:09:47	0:01	m:s	0	0
	10	63.5	64.0	65.5	76.0	3 MAY	7:09:58	0:01	m:s	0	0
	11	67.0	72.0	70.0	84.0	3 MAY	11:28:33	0:03	m:s	0	0
*	12	80.0	91.0	86.0	100.5	3 MAY	13:25:03	0:13	m:s	0	0
*	13	82.5	97.0	90.5	105.5	3 MAY	13:25:45	0:25	m:s	0	0
*	14	79.0	91.5	86.5	103.5	3 MAY	13:52:14	0:18	m:s	0	0
	15	65.5	72.0	67.0	82.0	3 MAY	13:52:41	0:04	m:s	0	0
*	16	68.5	83.5	74.5	92.5	3 MAY	13:52:53	0:33	m:s	0	0
	17	64.0	65.5	66.5	101.0	3 MAY	14:07:43	0:01	m:s	0	0
	18	66.5	73.0	70.0	99.0	3 MAY	14:08:23	0:04	m:s	0	0
	19	63.5	65.0	66.0	93.0	3 MAY	14:10:14	0:01	m:s	0	0
	20	66.0	76.0	67.5	84.0	4 MAY	8:47:22	0:09	m:s	0	0
	21	66.0	70.5	69.0	82.5	4 MAY	14:13:17	0:02	m:s	0	0
*	22	97.0	109.5	106.5	123.5	4 MAY	14:24:14	0:18	m:s	1	0
*	23	96.5	109.0	106.5	124.0	4 MAY	14:54:18	0:17	m:s	1	0
*	24	81.0	93.5	88.5	104.5	4 MAY	18:52:51	0:17	m:s	0	0
	25	66.0	70.5	68.5	82.5	5 MAY	11:41:31	0:02	m:s	0	0
	26	65.0	68.0	68.0	96.5	5 MAY	12:22:26	0:02	m:s	0	0
	27	64.0	67.0	66.5	91.0	5 MAY	12:22:34	0:01	m:s	0	0
cal	28	94.0	101.5	94.5	97.5	5 MAY	12:22:58	0:35	m:s	0	0

Figure 4-6. Sample Exceedance Report for IR-109, Site 15.
Calibration and Flyover Events (*) Noted.

4.4 Schedule Data and Measurement Correlation

Schedule data used in this study represents the records kept by the airspace managers. Data were collected after each flying day and included all scheduled missions which flew, and also included missions which were scheduled, but canceled.

Tables 4-1 through 4-3 contain the operation schedules for IR-109, IR-302, and VR-1753, respectively. Each table lists the date, entry time, type of aircraft, and number of aircraft for each mission. The final column lists the number of aircraft in each mission that were detected by the monitor array. A mission, in the following discussions, refers to a group of aircraft operating in formation (and usually scheduled together). Tables 4-1 through 4-3 do not include detected aircraft which were not scheduled for these routes.

4.4.1 IR-109 Flight Operations

Table 4-1 shows the schedule information for IR-109. All of the operations on IR-109 from 4 May to 1 June 1993 are listed. A total of 83 aircraft were scheduled in 45 missions, 72 of which were F-111s and 11 were EF-111s. Of the 83 aircraft that were scheduled during this period, only 12 (about 15 percent) went undetected by the monitoring array. Those that went undetected may have aborted due to bad weather, left the route before reaching the monitoring array, or passed through the array near the route boundaries where the monitors were spaced up to 1 nautical mile apart.

In addition to the scheduled flights, 27 missions (consisting of 39 aircraft) were measured which did not appear on the schedule. Because the distribution of sound levels for these events was similar to that for the scheduled events, it is likely that all the unscheduled events were F-111s or EF-111s. Of the 27 unscheduled missions, 18 consisted of a single aircraft. The total number used in the statistical analysis was 110 aircraft within 70 missions: the total of all detected aircraft, scheduled and unscheduled.

Table 4-1

IR-109 Flight Operations Schedule

Date	Entry Time	Aircraft Type	No. of Aircraft	Number Identified
4 May 1993	0958	EF111	1	1
	1042	EF111	1	1
	1454	F111F	1	1
	1743	F111F	2	2
	1838	F111F	1	1
	1913	F111F	2	2
	1958	F111E	1	1
	2027	F111G	3	3
	2054	F111F	2	2
	2147	F111F	1	1
5 May	1016	EF111	3	2
7 May	1205	F111F	1	1
11 May	1113	F111E	1	1
	1313	F111F	3	3
	1543	F111F	1	1
	1643	F111G	2	0
	1756	EF111	2	1
	1913	F111F	3	2
	1943	F111F	3	3
	1954	F111F	2	2
12 May	1035	F111G	4	2
14 May	0935	F111G	4	4
	1215	F111F	2	2
	1245	F111F	2	2
18 May	1011	F111G	2	0
	1219	F111F	2	2
	1343	F111F	1	1
	1934	F111F	3	3
	2008	F111F	1	1
19 May	1102	F111E	2	2
21 May	0939	EF111	2	2
	1145	F111F	3	1
	1239	F111F	1	1
	1315	F111F	2	2
25 May	1317	F111G	2	2
	1618	F111F	2	2
1 June	1017	F111F	2	2
	1158	EF111	1	1
	1201	EF111	1	1
	1524	F111F	1	1
	1554	F111F	1	1
	1918	F111F	3	2
	1954	F111E	1	1
	2152	F111F	1	1
	2154	F111F	1	1
TOTALS		45 Missions	83 Aircraft	71 Identified

Table 4-2
IR-302 Flight Operations Schedule
(including three flights on VR-1300 and VR-1304)

Date	Entry Time	Aircraft Type	No. of Aircraft	Number Identified
13 October 1994	1230	B-1	2	2
21 October*	1530	EA6B	1	0
	1550	EA6B	1	0
	1825	F-18	2	0
22 October	1000	AV8	2	2
24 October*	1030	F-111	2	0
25 October	1923	F-15E	4	4
29 October*	1245	EA6B	1	0
	1315	EA6B	1	0
	1345	EA6B	1	0
2 November	1340	F-15E	1	1
8 November	1500	B-1	1	1
9 November	1635	B-52	2	1
10 November*	0926	B-1	2	0
	0946	B-1	2	0
11 November	0926	B-1	2	2
	1016	B-1	2	2
14 November	0926	B-1	2	2
	1016	B-1	2	2
	1900	B-1	1	1
15 November	0926	B-1	2	2
	1016	B-1	2	2
16 November	0926	B-1	2	2
	1016	B-1	2	0
17 November*	0926	B-1	2	0
	1016	B-1	2	0
18 November	1200	B-1	3	3
	1220	EA6B	1	1
22 November	1035	F-4	2	0
23 November	1035	F-4	2	1
28 November	1138	F-15E	4	1
	1223	F-4	2	1
30 November	1450	B-52	1	1
1 December	1115	F-15E	3	1
6 December	1305	F-4	2	0
	1455	B-1	1	0
	1535	B-52	2	2
7 December	1136	F-4	2	0
8 December	1000	B-1	2	1
	1240	A-6	1	1
13 December	1930	B-1	2	0
	2100	B-1	1	0
14 December	1003	B-52	2	2
TOTALS		43 Missions	79 Aircraft	41 Identified

* Rain or Inclement Weather.

Table 4-3

VR-1753 Flight Operations Schedule

Date	Entry Time	Aircraft Type	No. of Aircraft	Number Identified
14 March 1995	1145	F-14	1	1
	1200	F-14	1	1
	1700	F-14	3	1
15 March	1645	F-14	1	1
16 March	1230	F-14	1	1
	1500	F-14	2	2
	1515	F-14	1	1
	1700	F-14	4	0
17 March	0800	F-14	2	2
	1115	F-14	2	2
	1230	F-14	4	4
20 March	0900	F-14	4	1
	0915	AV8	1	1
	1030	F-14	2	1
	1045	F-14	2	2
	1445	F-14	1	1
	1615	F-14	4	1
	2100	A6	1	1
21 March	1600	F-14	2	2
22 March	0830	A6	5	2
	0930	F-15E	2	1
	1330	F-16	2	2
	1345	F-14	2	2
	1400	F-14	2	2
	1415	F-14	2	2
	1445	AV8	2	2
23 March	0830	A6	5	0
	1030	F-14	2	0
	1915	F-16	2	2
	2145	F16	2	0
24 March	0830	A6	5	5
	1115	F-14	1	1
27 March	1000	F-15E	2	2
	2015	A6	1	1
	2030	A6	1	1
29 March	1015	F-15E	2	2
30 March	1000	F-15E	2	2
31 March	0830	A6	5	5
	0845	A6	5	5
	1445	A6	5	1
4 April	1630	F-14	4	4
	1845	A6	5	1
5 April	1845	A6	4	2
	2130	A6	5	1
7 April	1515	A4	1	1
	1800	A4	1	1

Table 4-3 (Continued)

Date	Entry Time	Aircraft Type	No. of Aircraft	Number Identified
11 April	0915	A6	1	1
	1845	A6	5	3
12 April	2145	A6	2	1
13 April*	1945	A6	2	0
	2145	A6	5	0
17 April	0745	F-14	5	1
	1015	F14	2	0
18 April	1130	A6	1	0
	1300	F14	2	1
20 April	1030	F-14	2	2
	1115	F-14	2	0
24 April	0915	F-14	2	0
	0945	F14	2	0
	1015	A6	2	1
	1100	F14	2	0
	1130	A6	2	1
	1330	F14	2	1
25 April	0900	F14	2	0
	1100	F14	2	0
	1130	A6	2	1
	1215	A6	2	0
	1230	EA6B	1	0
	1300	A6	2	0
	1330	F14	2	1
	1530	A6	2	1
	1630	F14	2	0
26 April	1100	A6	2	2
	1145	A6	1	0
	2030	A6	2	0
27 April	0630	F-14	2	1
	0915	A6	1	1
	1100	A6	1	0
	1130	A6	2	1
	1230	A6	2	1
	1330	F-14	2	1
28 April	0730	F14	1	0
1 May	1130	F14	4	1
2 May*	0745	F14	2	0
3 May	0745	F14	2	1
	1015	A6	2	0
	1315	A6	2	0
4 May	0830	EA6B	1	1
TOTALS		88 Missions	203 Aircraft	101 Identified

* Rain or Inclement Weather.

4.4.2 IR-302 Flight Operations

The schedule data for IR-302 for the measurement period 13 October through 14 December 1994 is listed in Table 4-2. A total of 43 missions were flown during this period. Of these 43 missions, 20 were B-1Bs, and the remainder included B-52s, EA-6Bs, F-111s, F-4s, F-15Es, F-18s, AV-8s, and one A-6. On several occasions, B-1Bs were observed crossing over the monitoring array, approximately 2 nautical miles south of the route centerline. Within these missions, 79 aircraft were scheduled, and 41 were detected by the noise monitors. Again, it is possible that these undetected aircraft either did not fly the route or exited prior to passing over the array. Another possibility is that aircraft were flying outside of the 10-nautical-mile-wide corridor centered on the route centerline.

No unscheduled flights were detected by the noise monitors. Three aircraft were detected that corresponded to operations on the overlapping airspaces VR-1300 and VR-1304; these were included in the analysis. Forty-one aircraft, contained within 25 missions, were used in the statistical analysis.

4.4.3 VR-1753 Flight Operations

Table 4-3 lists the schedule data for VR-1753 during the measurement period of 14 March to 4 May 1995. A total of 88 missions consisting of 203 aircraft were scheduled during this period. Of these 88 scheduled missions, 42 were F-14s, 33 were A-6s, and the remainder consisted of F-15Es, F-16s, AV-8s, and EA-6Bs.

There were no unscheduled flights detected on this route. Of the 203 scheduled aircraft, 101 (or about 50 percent) were detected by the noise monitors and subsequently used in the statistical analysis. It is possible that aircraft scheduled but not detected flew outside of the bounds of the noise monitoring array. This will be discussed more in Section 4.5.3.

4.5 MTR Measurement Results

The discussion of the measurement results revolves around several figures which require some introduction. There are four figures for each of the three routes. Figures 4-7 through 4-10 correspond to IR-109 and consist of the following:

- Figure 4-7 shows the distribution of aircraft recorded by the measurement arrays. The positions of individual aircraft were assumed to be over the monitor site which recorded the maximum level. In each figure a plot of the raw data and smoothed data are shown. The smoothed data was calculated from the weighted average of the site and the two sites adjacent to it. The site was weighted 50 percent and the two adjacent sites were weighted 25 percent. Since the total number of events at any particular site were statistically low, the smoothed distribution is probably a better representation of the data.
- Figure 4-8 shows the cumulative probability distribution of position. In the case of a perfectly Gaussian distribution, this plot would appear as a straight line. Each of these plots contains the individual site data points along with an ideal Gaussian straight line for comparison.
- Figure 4-9 shows the total number of events recorded at each site. This represents the number of aircraft which exceeded the monitor threshold level of 65 to 70 dB during the measurement period.
- Figure 4-10 shows the distributions of the measured sound exposure level and maximum level. These are the maximum for each event, and represent noise levels occurring within half the monitor spacing of the flight track. In addition, the measured levels are split between scheduled and unscheduled events.

In this series of figures, the first two are used to define the flight track distribution while the last two indicate the measured noise environment.

4.5.1 IR-109 Measurement Results

The distribution obtained for IR-109, shown in Figure 4-7, has a mean of 1.58 nautical miles and a standard deviation of 1.62 nautical miles. The offset of the distribution, east of the centerline, is most likely due to higher terrain located west of the centerline. Cuervo Hill is located less than 1 nautical mile west of the centerline causing aircraft to fly to the east, as shown.

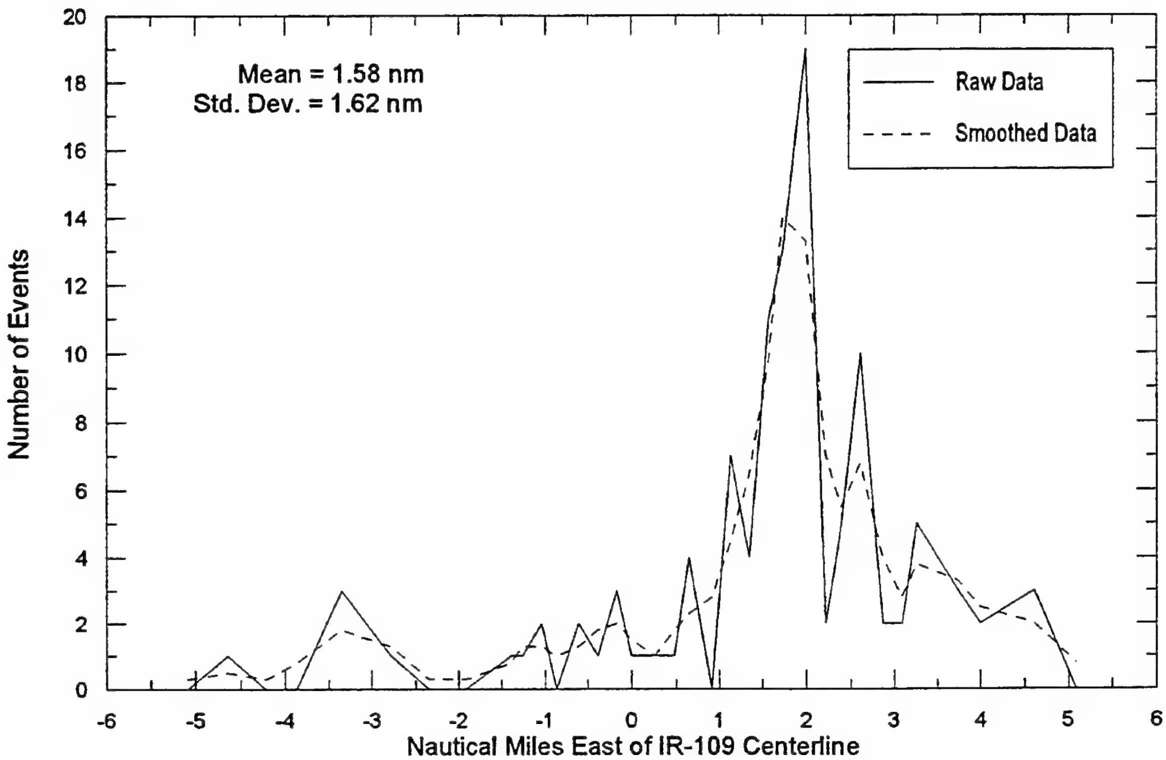


Figure 4-7. IR-109 Event Distribution.

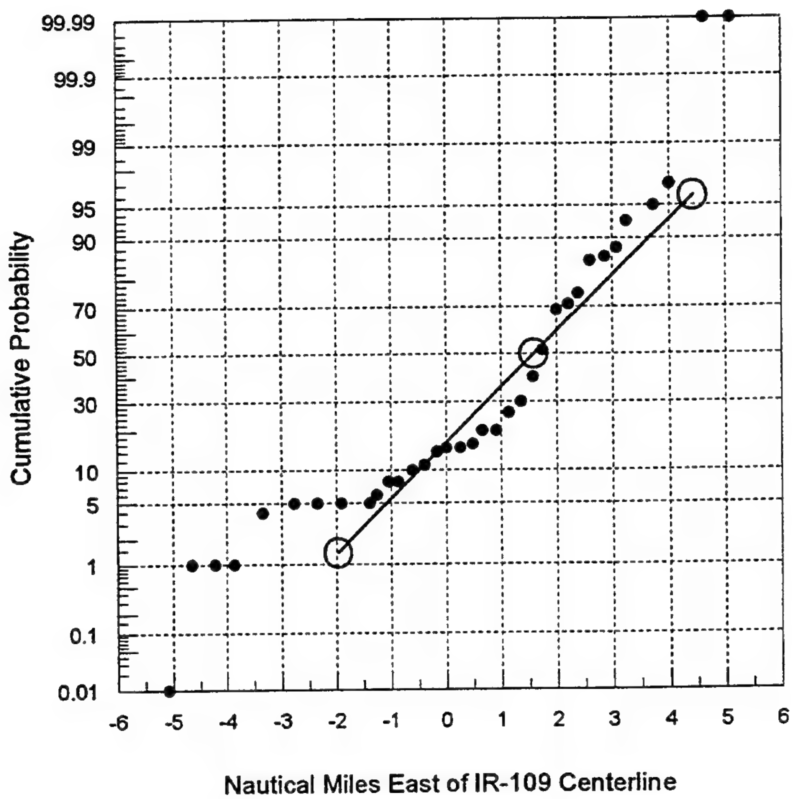


Figure 4-8. IR-109 Event Cumulative Probability Distribution.

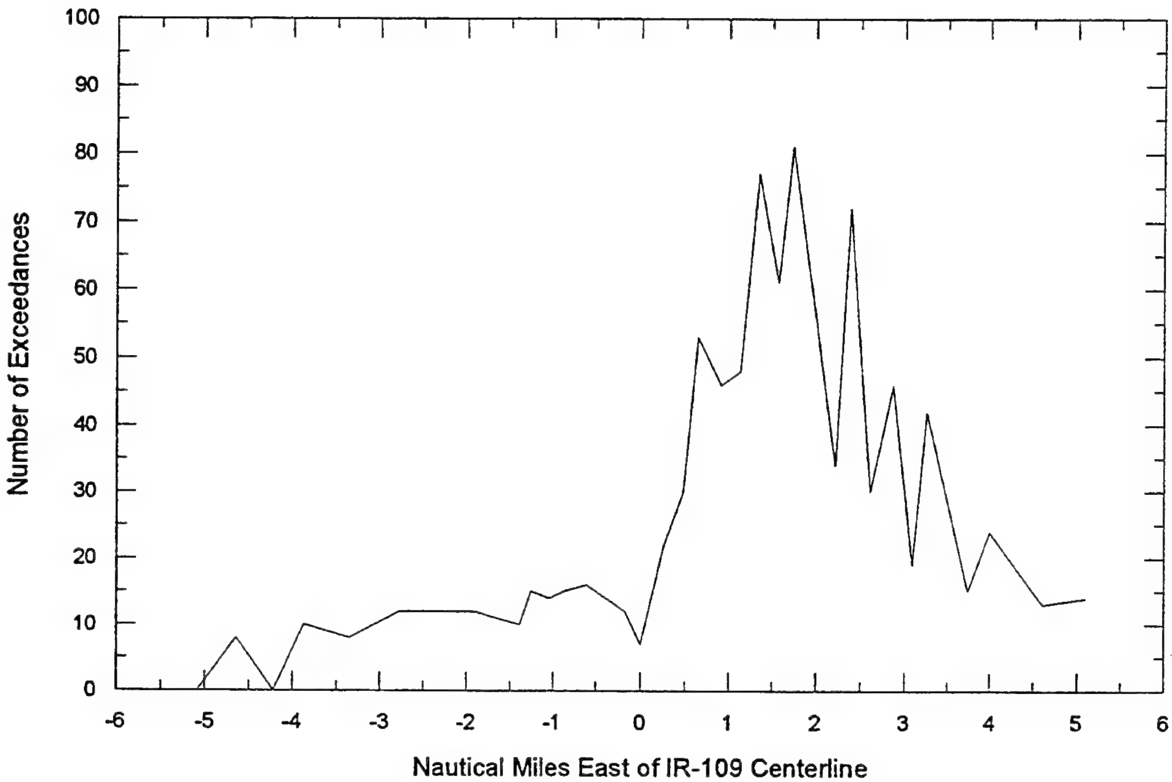
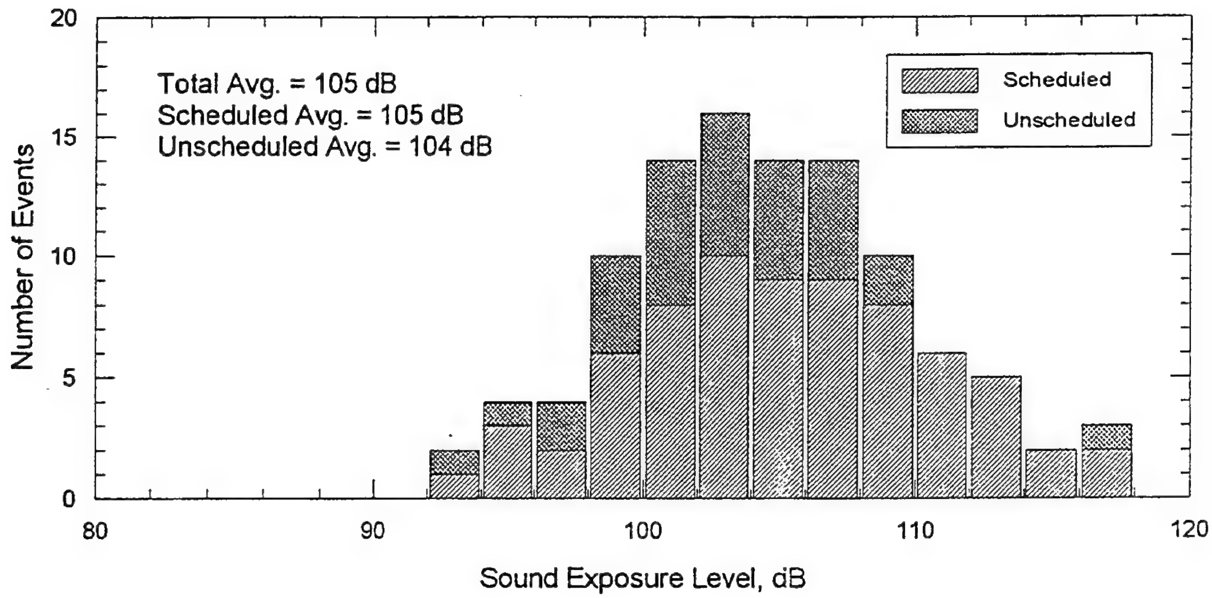
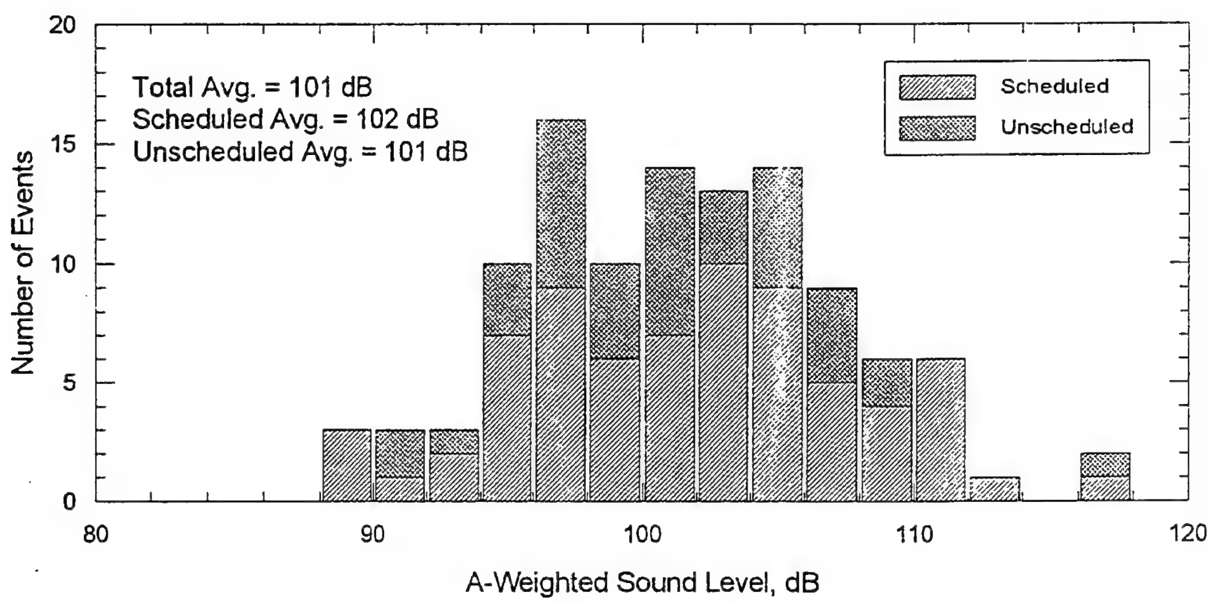


Figure 4-9. IR-109 Total Events at Each Site.



(a) Distribution of Highest SEL for Each Event.



(b) Distribution of Highest Maximum Level for Each Event.

Figure 4-10. Distribution of Event Sound Levels, IR-109.

The cumulative probability distribution for IR-109 is shown in Figure 4-8. If the data were perfectly Gaussian, it would appear as a straight line on the probability plot. A line has been drawn on Figure 4-8 corresponding to a Gaussian distribution having a mean of 1.58 nautical miles and a standard deviation of 1.62 nautical miles. While the actual data follow the straight line fairly well, there is some deviation just east of the centerline and toward the edges of the route.

The total number of events recorded at each site are shown in Figure 4-9. These include all exceedances (i.e., sound levels above the threshold of 65 to 70 dB) associated with aircraft overflights, not just the maximum.

Figure 4-10(a) shows a histogram of the Sound Exposure Levels for all detected aircraft. The data are grouped in 2-decibel-wide bins according to the measured SEL values. The energy average sound level for this distribution is 105 dB. This average sound level can be used to approximate the average altitude for the F-111 and EF-111 operations. Using OMEGA108R and selecting the mid-speed training route profile for the F-111F (500 KTS at 90% NC), the corresponding altitude was calculated to be 400 feet AGL. The range of SELs shown in Figure 4-10 implies a significant variation in the altitudes flown.

The distribution in Figure 4-10(a) is also split between scheduled and unscheduled events. The energy average SEL was 105 dB for scheduled events and 104 dB for unscheduled events, indicating that the unscheduled events were, most likely, F-111s or EF-111s.

A similar plot is shown in Figure 4-10(b) for the maximum levels measured for the detected events. The energy average maximum level on IR-109 was 101 dB. The energy average maximum level was 102 dB for scheduled events and 101 dB for unscheduled events.

4.5.2 IR-302 Measurement Results

The distribution obtained for IR-302, shown in Figure 4-11, has a mean of 0.44 nautical mile and a standard deviation of 2.94 nautical miles. The mean is within one-half nautical mile from the IR-302 centerline; however, the event distribution shows four peaks within the 9-nautical-mile distance covered by the monitoring array. The aircraft generally avoided a mountain peak located one to

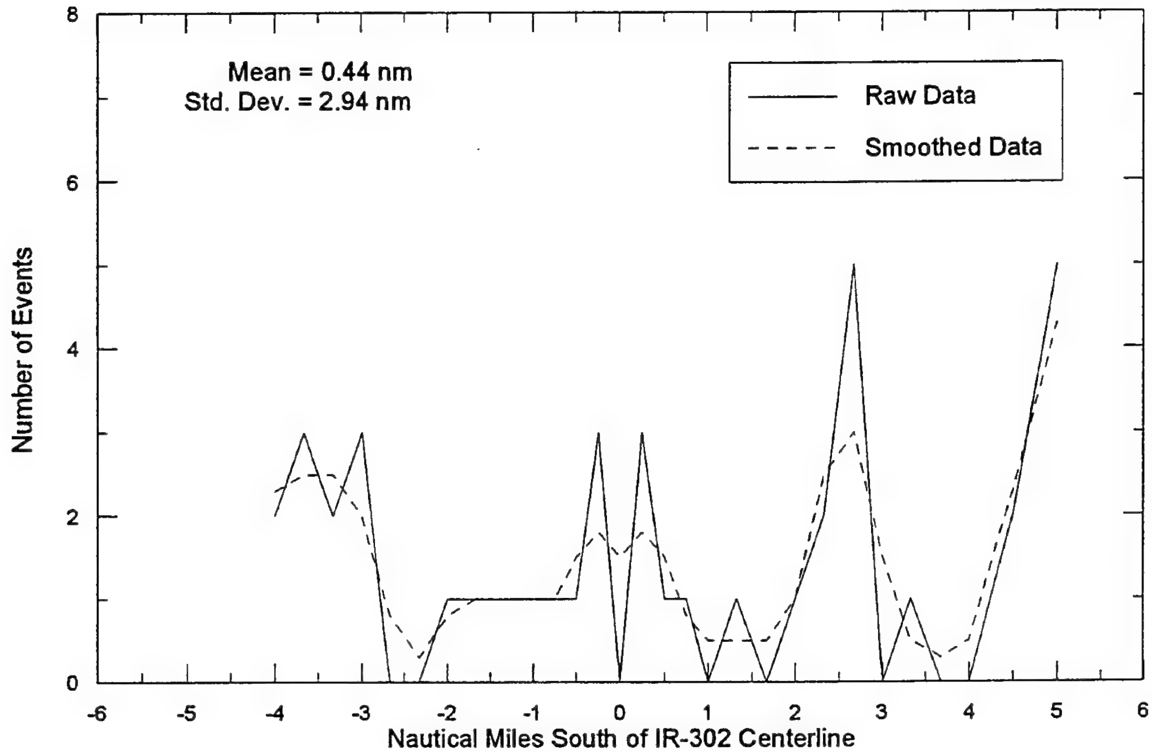


Figure 4-11. IR-302 Event Distribution.

two miles north and several miles east of the array centerline. This is shown by the low number of events detected at the monitoring positions one to two miles north of the centerline. Examining Figure 4-11, the spread in the event distribution indicates that pilots are flying this portion of the route using visual terrain avoidance navigation as there is no single defined track, and there are a number of flights occurring on either side of the noted mountain peak.

The cumulative probability distribution for IR-302 is shown in Figure 4-12. The data follow the straight line of an ideal normal distribution fairly well. The total number of exceedances measured at each site are shown in Figure 4-13.

Figure 4-14(a) shows the distribution of SELs for all measured events. The energy average associated with these measurements is 95 dB. All events corresponded to scheduled aircraft. Because of the wide variety of aircraft that used this route during the monitoring period, no attempt was made to quantify operating altitudes. Figure 4-14(b) is the distribution of maximum levels which has an energy average of 90 dB. The measured SEL and maximum levels are distributed in 2 dB wide bins.

4.5.3 VR-1753 Measurement Results

The distribution of events along VR-1753, shown in Figure 4-15, has a mean of -1.26 nautical miles and a standard deviation of 0.80 nautical mile. The location of the mean, in this case, reflects the fact that flight operations are restricted to an approximate 2-nautical-mile-wide corridor of airspace, 1 to 3 nautical miles north of the centerline. Flight operations on this segment were influenced by an avoidance area centered on the town of Disputanta, Virginia. The event distribution indicates, however, that roughly one-third of the detected aircraft flew within the avoidance area. While most of the detected aircraft that entered the avoidance area remained within 0.5 nautical mile of the southern boundary, it is unknown how many, if any, flew farther south of the route centerline and deeper into the avoidance area. It was not possible for these reasons to establish the effective route width (i.e., flight corridor) for this measurement.

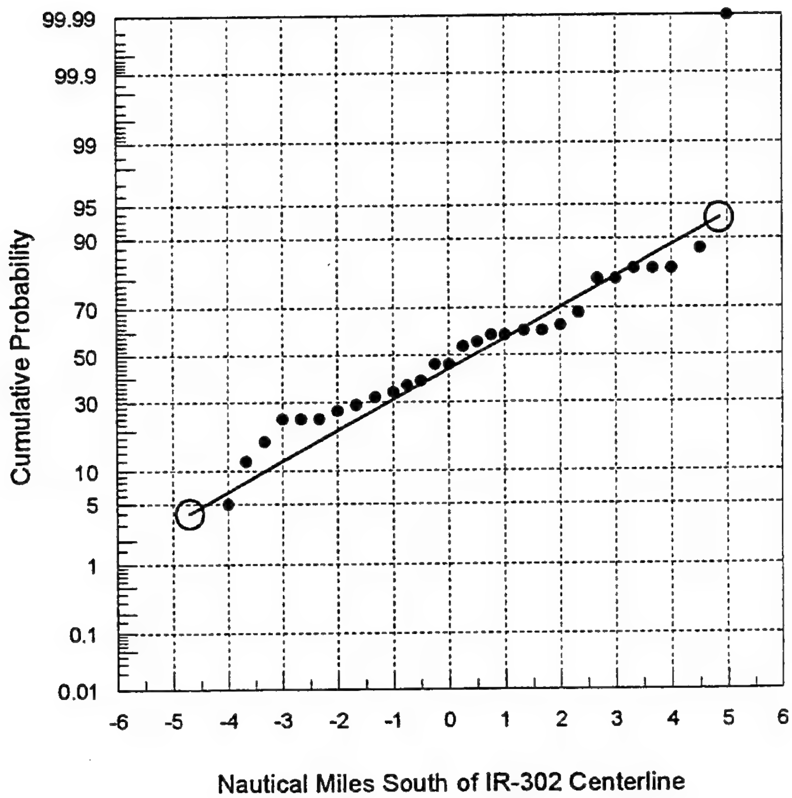


Figure 4-12. IR-302 Event Cumulative Probability Distribution.

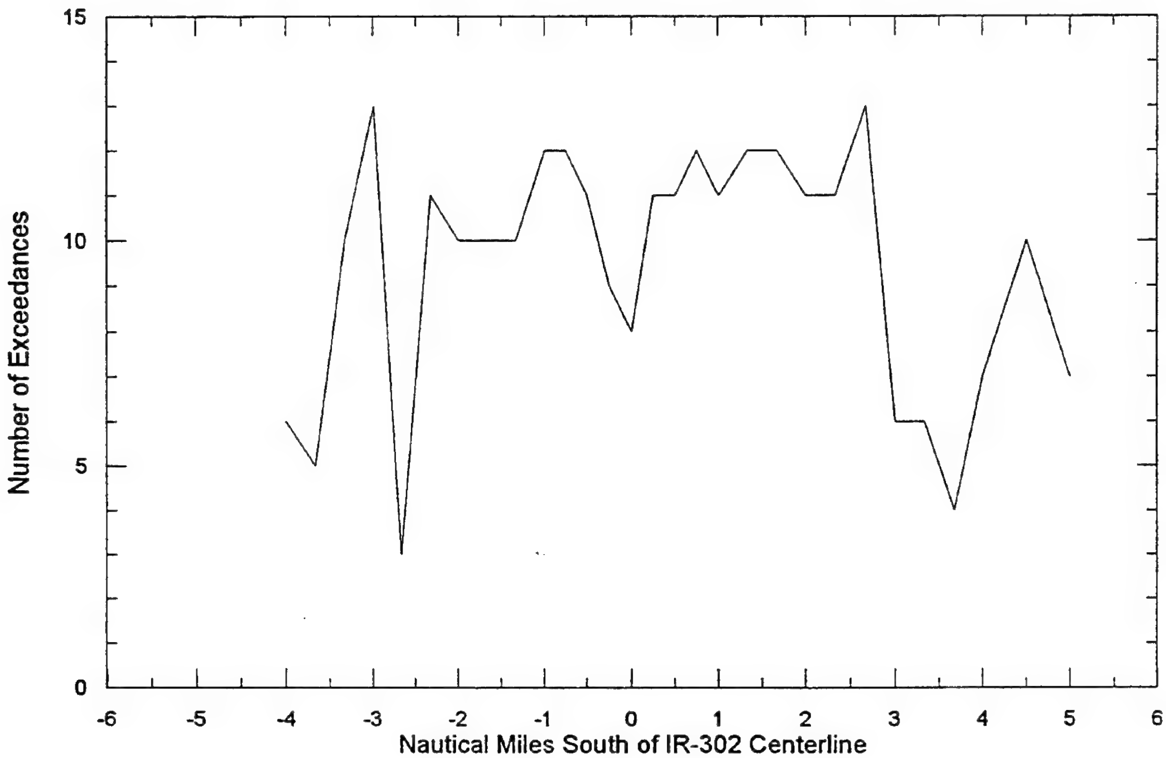
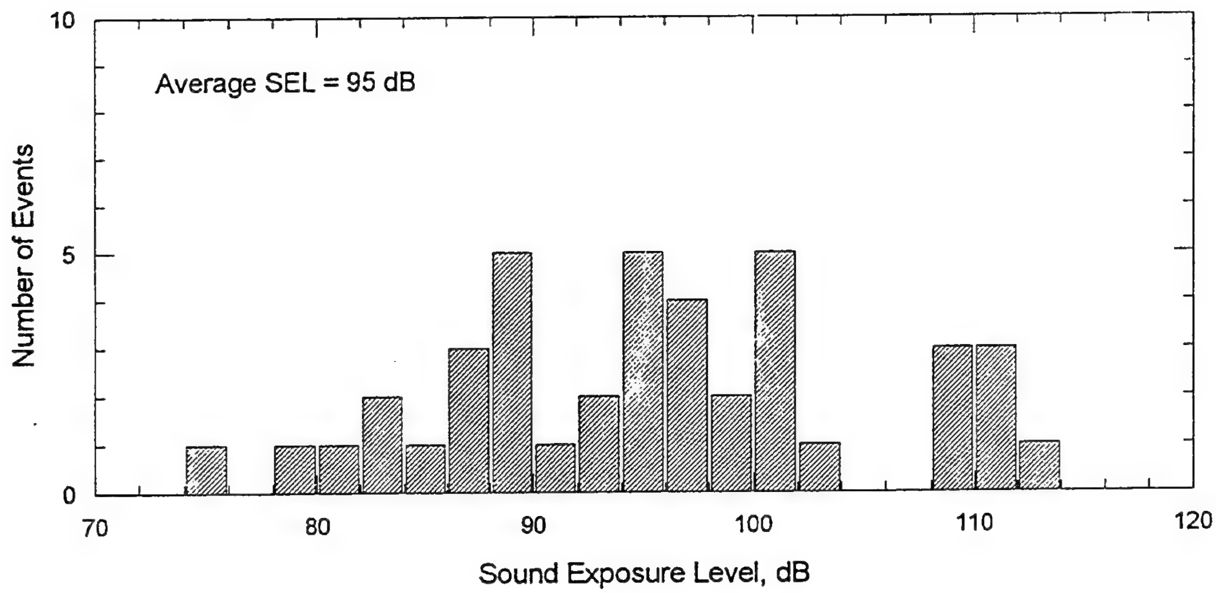
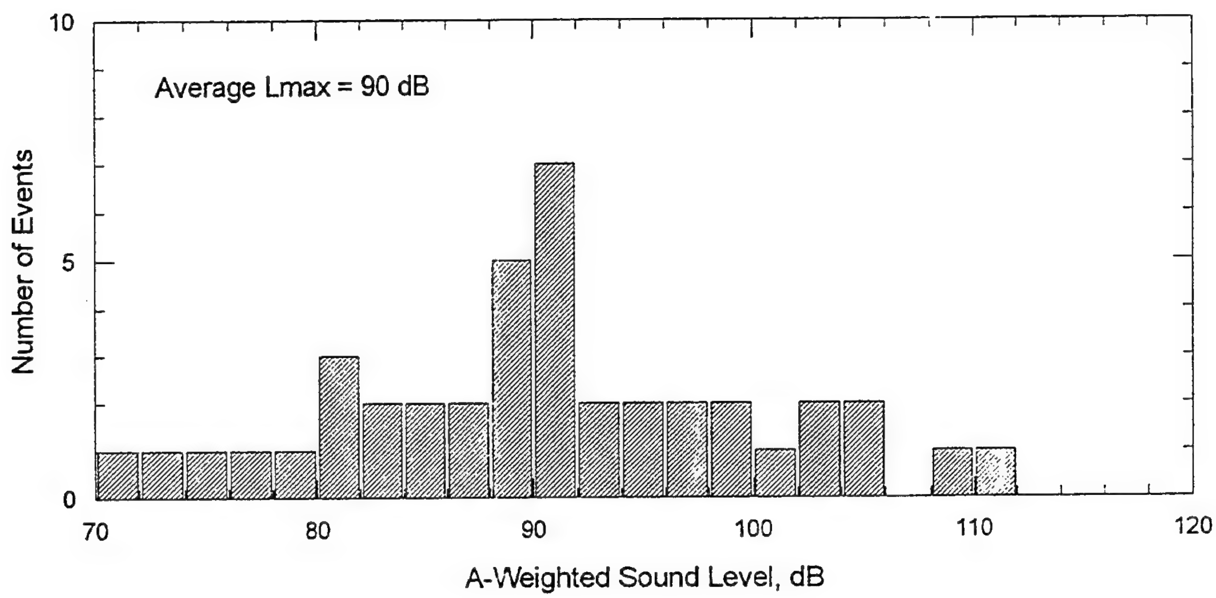


Figure 4-13. IR-302 Total Events at Each Site.



(a) Distribution of Highest SEL for Each Event.



(b) Distribution of Highest Maximum Level for Each Event.

Figure 4-14. Distribution of Event Sound Levels, IR-302.

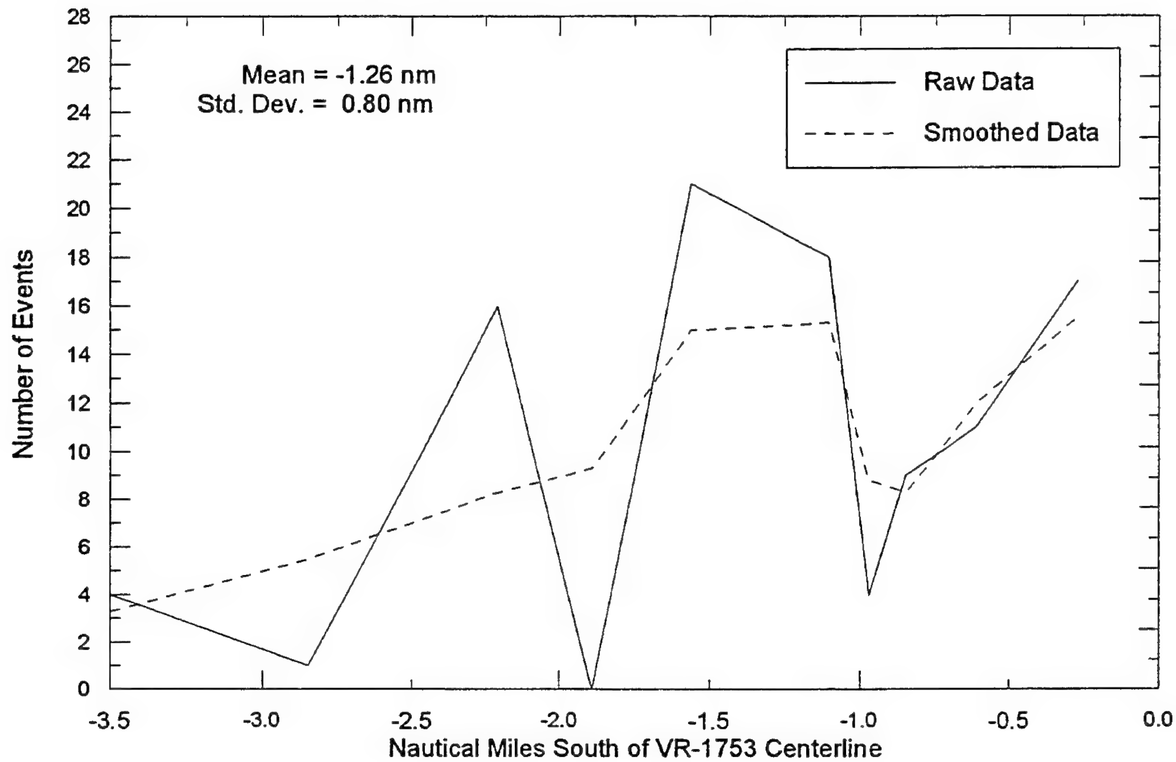


Figure 4-15. VR-1753 Event Distribution.

The cumulative probability distribution for VR-1753 is shown in Figure 4-16. The data follows the straight line of an ideal normal distribution fairly well within the expected flight corridor. The data point at -0.5 nautical mile south of the centerline represents events that occurred within the avoidance area.

The total exceedances measured at each site are shown in Figure 4-17.

The distribution of Sound Exposure Levels for VR-1753 is shown in Figure 4-18(a). The energy average for this distribution is 89 dB. Again, due to the wide variety of aircraft using this route, no attempts were made to estimate the aircraft altitudes over the monitoring array. The distribution of event maximum levels per 2 decibel bin is shown in Figure 4-18(b). The corresponding energy average is 84 dB.

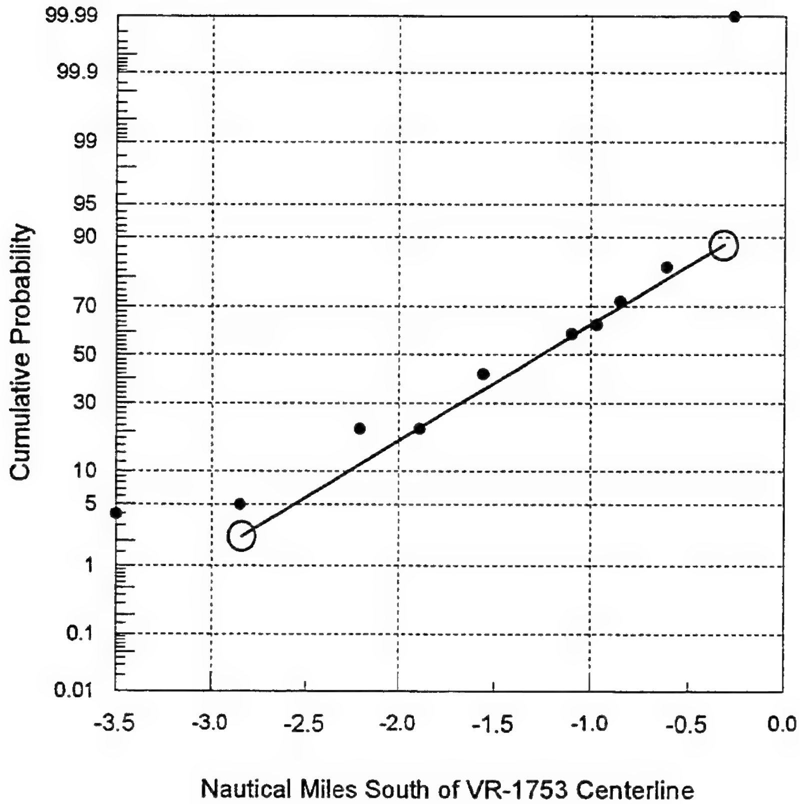


Figure 4-16. VR-1753 Event Cumulative Probability Distribution.

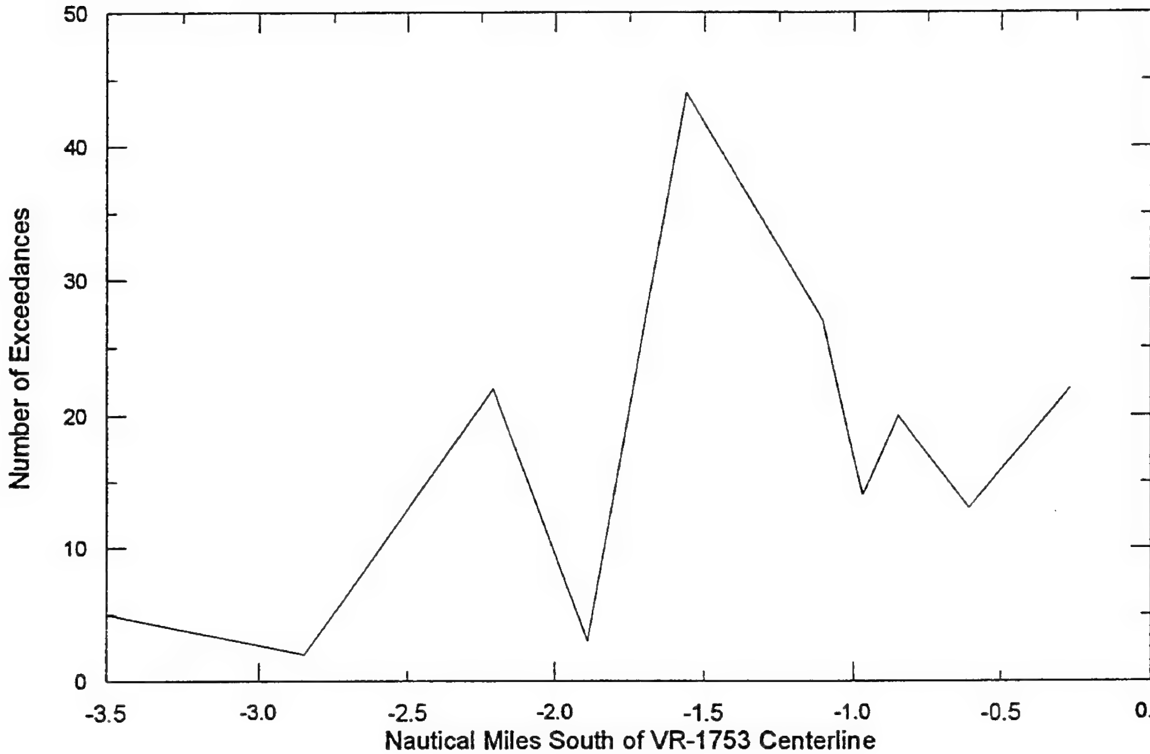
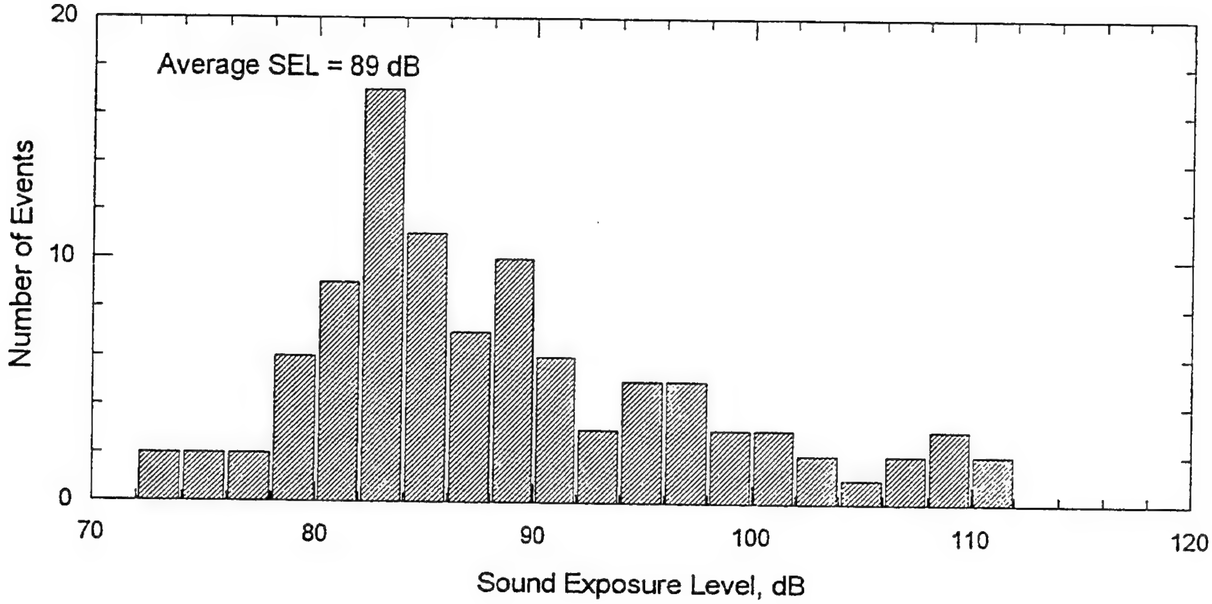
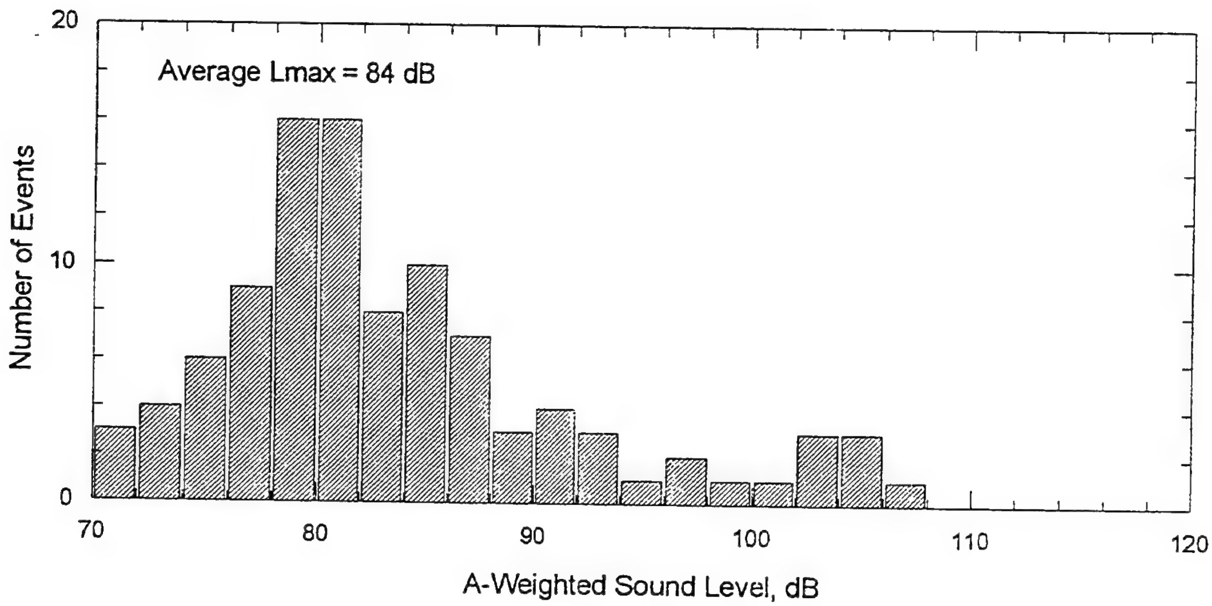


Figure 4-17. VR-1753 Total Events at Each Site.



(a) Distribution of Highest SEL for Each Event.



(b) Distribution of Highest Maximum Level for Each Event.

Figure 4-18. Distribution of Event Sound Levels, VR-1753.

5.0 CONCLUSIONS

Measurements of aircraft flight operations were performed on five Military Training Routes including IR-109 in New Mexico, IR-302 in Nevada, VR-1753 in Virginia, and IR-036 and VR-1041 in South Carolina. Acoustic measurements were conducted on IR-109, IR-302, and VR-1753. Radar tracking was used to obtain measurements on IR-036 and VR-1041. The objective of these measurements was to determine the lateral distribution of flight operations across various types of MTRs in order to validate or update the flight track dispersion algorithms used in the ROUTEMAP and MR_NMAP noise models.[9,10] These algorithms, which define the spread in aircraft position, are an integral part of the environmental assessment methodology used for predicting noise levels on MTRs and MOAs.

While measurements on the five routes in this study were intended to test the current flight track dispersion algorithms, which were developed from previous measurement studies,[2,4,5] all measurements associated with this research are presented in Table 5-1. Along with the date and measurement method, the following are reported for each MTR: the segment where the measurement was performed, route width, measured standard deviation of the lateral flight track distribution, and the ratio of the standard deviation divided by the route width for measurements of dispersed flight tracks (the measurements prior to June 1993 have established this ratio to be 0.17). The measurements associated with the current study are indicated using boldface type for the MTR name. The radar tracking measurements along different sections of IR-036 and the coincident parts of IR-035 and IR-036 are considered as one of the five current measurements.

All measurements in Table 5-1, and specifically those associated with the current study, can be compared to the interim rules for specifying flight track dispersion on MTRs. As utilized in the ROUTEMAP and MR_NMAP models,[9,10] the rules shown in Table 5-2 are defined for various types of training missions. In all cases the dispersion is calculated assuming a Gaussian distribution of flight tracks; this has been tested and verified for measurements on IR-109, IR-302, VR-1753 and for most of the previous measurements. As indicated in Table 5-2, three current options are available for specifying the flight track dispersion; the conditions pertaining to the use of each are provided.

Table 5-1

Summary of MTR Flight Track Dispersion Measurements

Date	Measurement Method	MTR	Segment	Width (nm)	Std. Dev. (nm)	Std.Dev./ Width
April 87	Acoustic	VR-1066	B–C	13	2.5	0.19
June 87	Acoustic	VR-231	A–B	10	1.1*	
March 91	Acoustic	VR-1220	F–G	10	1.9	0.19
April 91	Acoustic	VR-223	A–B	4	0.9*	
November 91	Acoustic	VR-087	E–F	16	2.5	0.16
December 91	Acoustic	VR-088	C–D	20	3.6	0.18
February 92	Acoustic	VR-1074	B–C	10	1.7	0.17
June 93	Acoustic	**IR-109**	O–P	10	1.6	0.16
December 94	Acoustic	**IR-302**	J–K	16	2.9	0.18
May 95	Acoustic	**VR-1753**	B–C	3	0.8	
December 95	Radar	**IR-036**	D–E	10	0.7*	
December 95	Radar		E–F	10	1.4	0.14
December 95	Radar	**IR-035/IR-036**	Point F	12.61	3.3	0.26
December 95	Radar		F–G**	8	1.2	0.15
December 95	Radar		Point G	10	0.5*	
December 95	Radar		G–H[1]	10	0.5*	
December 95	Radar		G–H[2]	10	0.4*	
December 95	Radar	**VR-1041**	G–H	6	1.0	0.17

MTR measurements associated with the current study are indicated using boldface type.

* Measurement corresponding to distribution with single track.

** Asymmetric route segment.

[1,2] Different measurement locations along IR-036 segment G–H.
The segments listed for the IR-035 and IR-036 coincident airspace are referenced to the IR-036 segment names.

Table 5-2

Current Rules for Specifying Flight Track Dispersion on Military Training Routes

Flight Track Model	Condition of Use	Model Algorithm
A: Centerline Flight Tracks	Model for training missions conducted under Instrument Flight Rules (IR), using electronic navigation, and with a high degree of precision.	$\sigma = 0.43$ nm
B: Dispersed Flight Tracks	Model for training missions that use visual point-to-point navigation, on VR or IR routes, producing multiple tracks through the route corridor.	$\sigma = 0.17 \bullet w$, $w \geq 6$ nm 1.0 $w < 6$ nm
C: User Defined	Can be implemented when specific flight track dispersion data are available. It is recommended to use $\sigma = 1.0$ nm for routes wider than 6 nm, but with a single dominant track.	0.34 nm $\leq \sigma \leq$ 5.1 nm

The following are comparisons of the current measurement results to the relevant flight track dispersion model.

A. Centerline Flight Tracks

Measurements of C-17 aircraft, flying a high precision approach to a cargo drop zone, were conducted along the IR-035 and IR-036 coincident segments at points G, G–H[1], and G–H[2]. The standard deviations associated with the flight tracks at these points are 0.5, 0.5, and 0.4 nautical miles, respectively. These three measurements are of the same operation, however, conducted at different points along the approach track. These results can be compared to the model for "centerline flight tracks", where the standard deviation is 0.43 nautical mile.

B. Dispersed Flight Tracks

Measurements were conducted on IR-109, IR-302, VR-1753, IR-036 segment E–F, IR-035 and IR-036 coincident segments (point F and segment F–G), and VR-1041 segment F–G. The measured flight track distributions for the IR routes indicated that operations were dispersed along the flight corridor. The ratio of the standard deviation devided by the route width, for measurements where the route width was greater than 6 nautical miles, are as follows: IR-109 (0.16), IR-302 (0.18), IR-036 segment E–F (0.14), IR-035 and IR-036 point F (0.26) and segment F–G (0.15), and VR-1041 segment G–H (0.17). Previous measurements that were used to develop this ratio include VR-1066 (0.19), VR-1220 (0.19), VR-087 (0.16), VR-088 (0.18), and VR-1074 (0.17).

Measurements of flight tracks within a corridor less than 6 nautical miles wide are represented by VR-1753 ($\sigma = 0.8$ nm) and VR-223 ($\sigma = 0.9$ nm); however, a dominant track was observed within the distribution. For routes less than 6 nautical miles wide, the current model uses a standard deviation, σ, of 1.0 nautical mile.

C. *User Defined*

The distributions for IR-036 segment D–E and VR-231 segment A–B indicate that aircraft use a single dominant track. These routes are greater than 6 nautical miles wide at the measurement point. While ROUTEMAP and MR_NMAP provide flexibility in defining the standard deviation of known tracks, the recommended value for this situation is 1.0 nautical mile.[5] The standard deviations measured for IR-036 segment D–E and VR-231 segment A–B are 0.7 and 1.1 nautical miles, respectively.

The results associated with the five current measurements confirm each of the appropriate rules for modeling flight track dispersion, with the exception of the measurement at point F along the coincident IR-035 and IR-036 segments. The measured distribution includes two single defined tracks on IR-036, associated with the turn at point F, along with the single defined track originating from IR-035. In this case, the three distinct tracks should be modeled separately. Interestingly, if only the flight tracks associated with IR-036 are considered, the ratio of the standard deviation to the route width is 0.16, as presented in Table 3-2.

Based on the previous MTR measurements[2,4,5] used to develop the interim rules for modeling flight track distributions on MTRs and the results of the current study of five MTRs, it is recommended that the interim rules be formally adopted for use by the ROUTEMAP and MR_NMAP models.[9,10] These rules are as stated in Table 5-2.

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APPENDIX A

Source–Noise Measurements for the F-16C Block 52, F-15E, and F-4G Aircraft Operating at MTR Flight Conditions

Source-noise data for military aircraft are collected to support environmental assessments for military installations, Military Training Routes, Restricted Areas, and Military Operating Areas. Audio recordings of high-speed aircraft operations, as would occur on MTRs, MOAs, and Restricted Areas, are analyzed with the resulting data being added to the ROUTEFILE database. This database is used in the ROUTEMAP and MR_NMAP models.[A1,A2] Likewise, data obtained from aircraft operating at lower speeds, as would occur around installations, are included in the NOISEFILE database which is used in the NOISEMAP model.[A3,A4]

A survey was conducted to collect source-noise data for the F-16C Block 52 with small inlets (F100-PW-229), F-15E (F-100-PW-220E), and F-4G (J-79-GE-17E) aircraft operating over a range of high-speed MTR flight conditions. Audio recordings were obtained for the F-16C Block 52 and F-15E on 16 May 1995 and for the F-4G on 18 May 1995. The measurements were conducted in the southeast quadrant of the Saylor Creek Bombing Range at Mountain Home AFB, Idaho, as shown in Figure A-1. These measurements followed the official DoD procedure for recording high-speed aircraft overflight noise levels.[A5]

Aircraft acoustic signatures were recorded using six channels of a TEAC RD-145 digital audio data recorder along with Bruel & Kjaer 2639 preamplifiers and 4166 and 4165 microphones. The microphones were powered with Bruel & Kjaer 2804 power supplies. Each channel was calibrated before and after the measurements. During the measurements the microphones were covered with windscreens.

The microphones were positioned 1.2 meters above ground in a "T" formation as shown in Figure A-2. Two centerline microphones, separated by 500 feet, were placed along the line-of-flight. Four sideline microphones were spaced at intervals of 250 feet in a line perpendicular to the line-of-flight. One high-speed camera was used to record the aircraft altitude and lateral position during each overflight. The test site was relatively flat with soft ground cover and was free of any large reflecting objects. Weather conditions including the temperature, relative humidity, and wind speed and direction were monitored on a regular basis throughout the measurements.

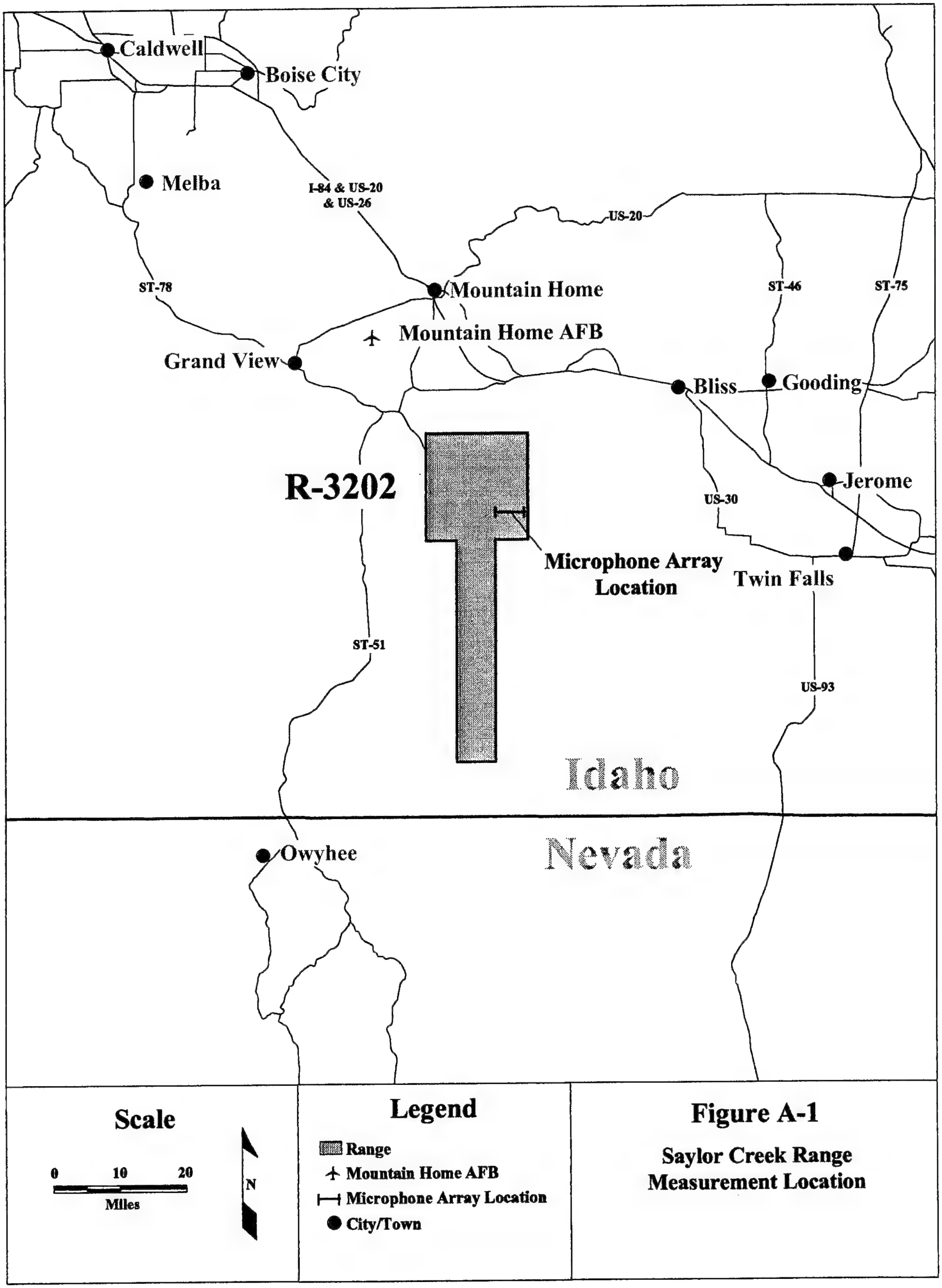


Figure A-1

Saylor Creek Range Measurement Location

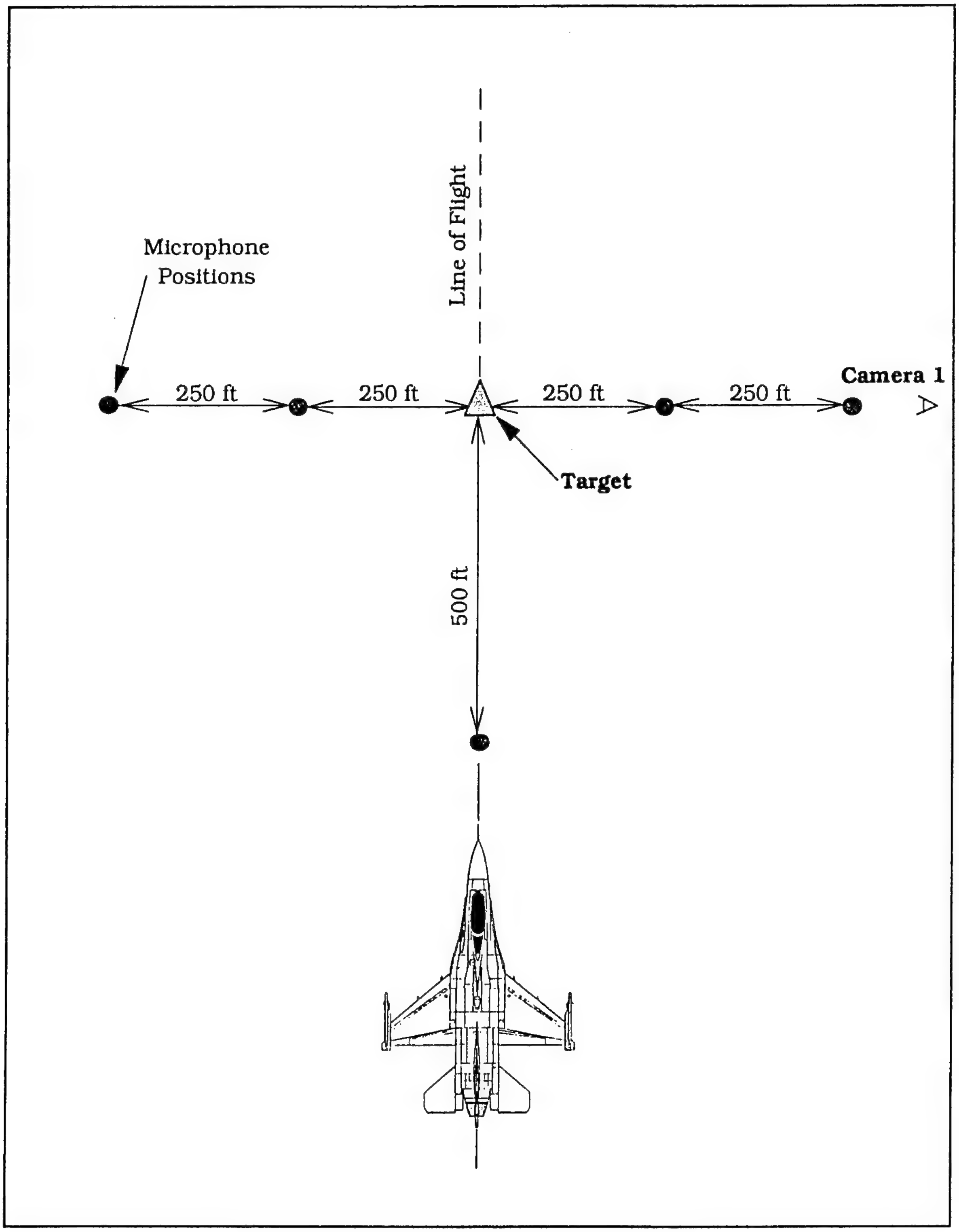


Figure A-2. Measurement Site Layout.

The direction of flight for each aircraft was due north over the array. The line-of-flight was designated by the run-in line to the east conventional drop zone which is used for target practice by tactical aircraft. Level flyovers were conducted over a range of airspeeds from 400 to 550 knots, typical of MTR operations. Table A-1 shows the nominal flight conditions proposed for use by the F-16C Block 52, F-15E, and F-4G aircraft. During the flyovers, pilots were instructed to maintain constant engine power, altitude, and speed setting for a distance of at least 5 nautical miles preceding and following passage over the microphone array. The values of these parameters and others related to engine performance were recorded for each flight. Tables A-2 through A-4 note the time over the array, altitude, power, and airspeed for each overflight as recorded by the pilots. The drag configurations for each aircraft were also noted; for example, the F-16C Block 52 carried two external fuel tanks, ECM pod, captive HARM, HARM pod, and two captive Sidewinders. Figure A-3 shows photographs of the overflights for each aircraft. The data recorder was activated when the aircraft was on approach, several nautical miles prior to the array. The recording continued until the aircraft was approximately 5 nautical miles beyond the array.

The acoustic recordings were processed in a coordinated effort with AL/OEBN, Wright-Patterson Air Force Base. A description of the processing techniques is described in References A6 through A8. The results of this analysis are one-third octave band data sets specifying the aircraft source-noise levels at a reference distance of 1,000 feet.

Four data sets were produced for the F-16C Block 52 aircraft as shown in Figure A-4. For each of the four power and speed conditions, the Sound Exposure Level (SEL) versus slant distance is plotted for air-to-ground sound propagation. The data sets corresponding to the flight conditions at 560, 490, and 440 knots ground speed (KGS) is included in the ROUTEFILE database. The data set associated with the 400 KGS condition is included in the NOISEFILE database since the noise signature did not exhibit spectral characteristics associated with high-speed flight (i.e., a noticeable peak in the frequency range of 630 to 1000 Hz, indicating aerodynamic effects). This data compares favorably with a similar set of measurements for the F-16C, with identical engine type, taken at Edwards AFB in 1991. The data obtained at Edwards was for low-speed conditions, so an airspeed adjustment was implemented to compare both sets of data.

Similar data sets for the F-15E and F-4G are to be included in the appropriate database.

Table A-1

Nominal Flight Conditions for
F-16C Block 52, F-15E, and F-4G Aircraft

Run No.	Airspeed (KTAS)	Altitude (Ft AGL)
1	550	500
2	500	500
3	440	500
4	400	500
5	550	1,000
6	500	1,000
7	440	1,000
8	400	1,000
9	550	500
10	500	500
11	440	500
12	400	500

Table A-2

Pilot Data Sheet for F-16C Block 52 Overflights

Run No.	Time	AGL	% RPM	KIAS	KTAS	KGS
1	1237	500	91	535	570	570
2	1241	500	89	460	500	490
3	1246	500	86	415	445	445
4	1251	500	85	380	400	400
5	1257	1,100	93	530	560	560
6	1300	1,020	89	465	500	500
7	1305	1,010	86	410	440	450
8	1311	980	85	380	410	410
9	1316	480	94	530	550	550
10	1321	520	89	460	490	490
11	1325	560	86	410	440	440
12	1331	520	85	380	405	405
13	1335	530	93	530	560	560

Table A-3

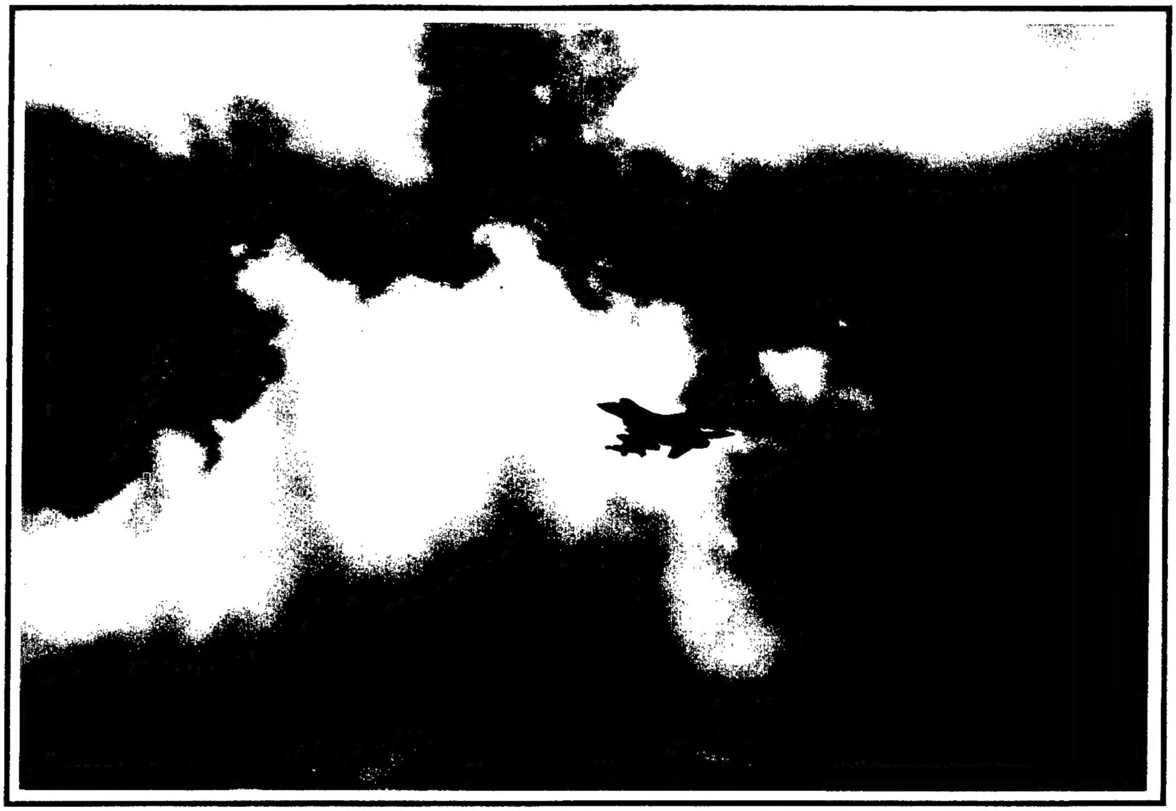
Pilot Data Sheet for F-15E Overflights

Run No.	Time	AGL	% RPM	KIAS	KTAS	KGS
1	1345	500	88	520	555	554
2	1351	580	87	460	492	490
3	1355	560	84	433	464	460
4	1401	590	84	382	406	409
5	1406	1,120	90	520	560	565
6	1410	1,150	86	460	500	493
7	1415	1,070	85	430	462	463
8	1421	1,120	85	395	418	410
9	1425	600	88	521	555	551
10	1430	580	86	468	500	498
11	1435	610	85	410	440	439
12	1440	399	81	376	400	399

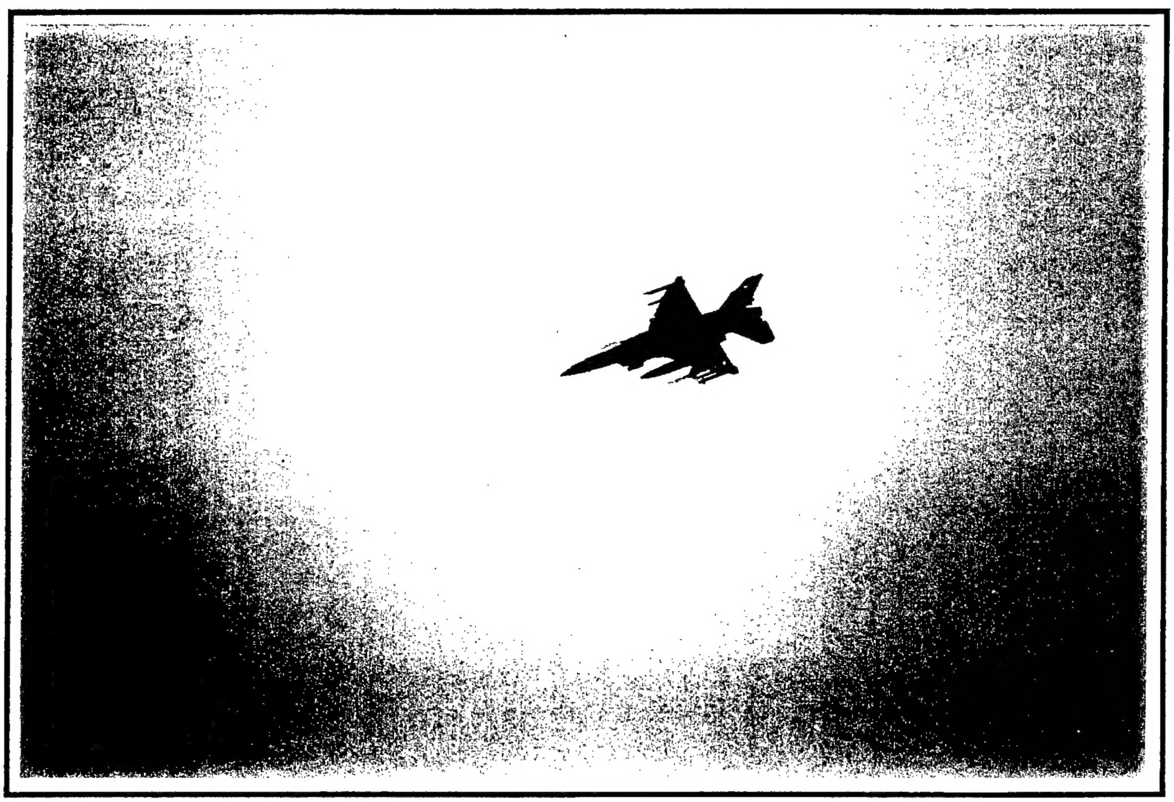
Table A-4

Pilot Data Sheet for F-4G Overflights

Run No.	Time	AGL	%RPM	KIAS	KTAS	KGS
1	1437	500	96	510	548	539
2	1441	490	93	460	505	509
3	1446	500	90	420	444	435
4	1450	450	88	370	399	396
5	1454	1,000	94	510	550	547
6	1457	950	95	480	518	510
7	1500	1,000	91	430	451	448
8	1502	1,000	87	370	392	389
9	1504	500	96	530	558	554
10	1506	500	92	470	490	488
11	1508	500	90	410	448	443
12	1510	490	87	380	395	389
13	1514	520	100	560	591	588

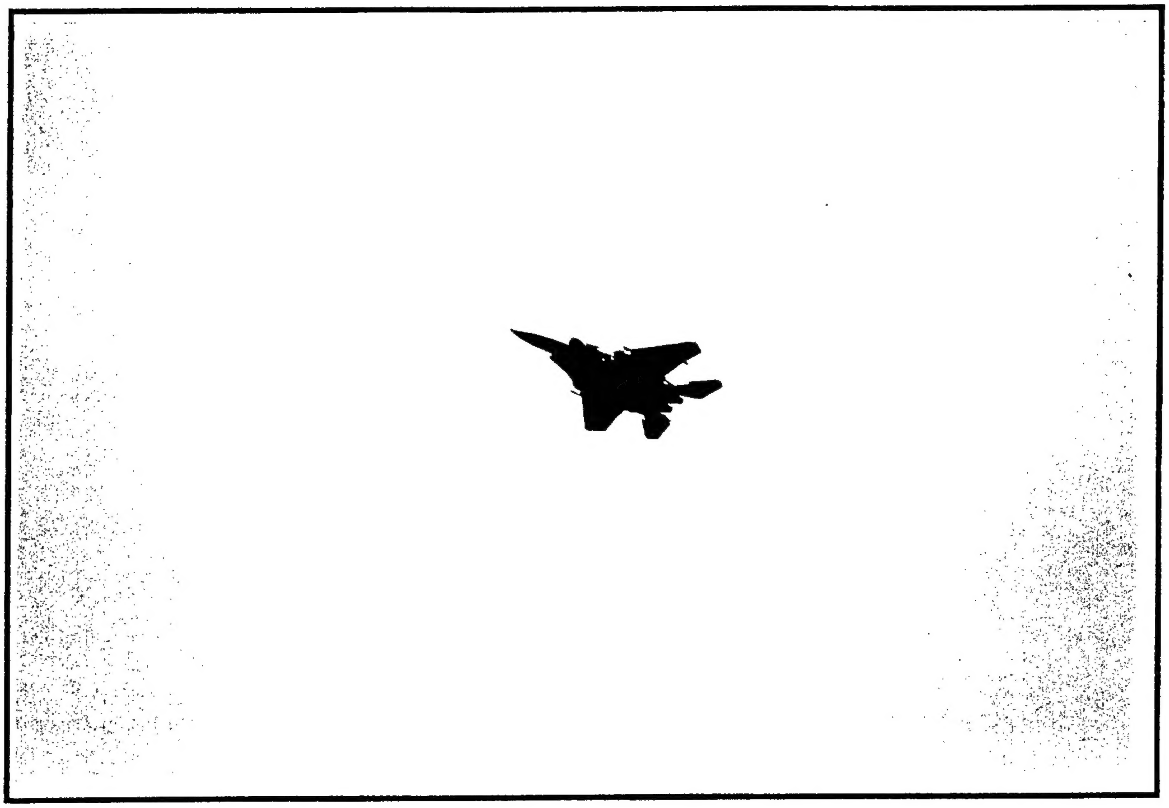


(a) F-16C Block 52 Approach.

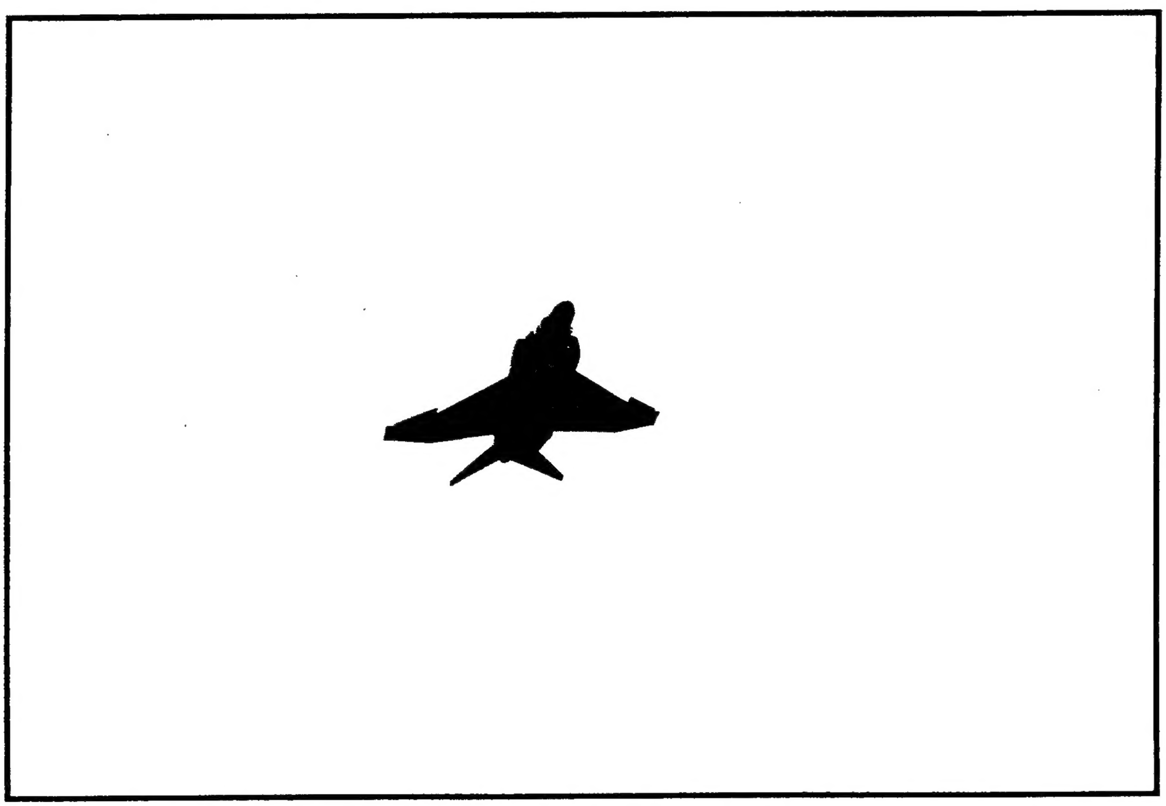


(b) F-16C Block 52 Over Microphone Array.

Figure A-3. Aircraft Overflights Observed During the Measurements.

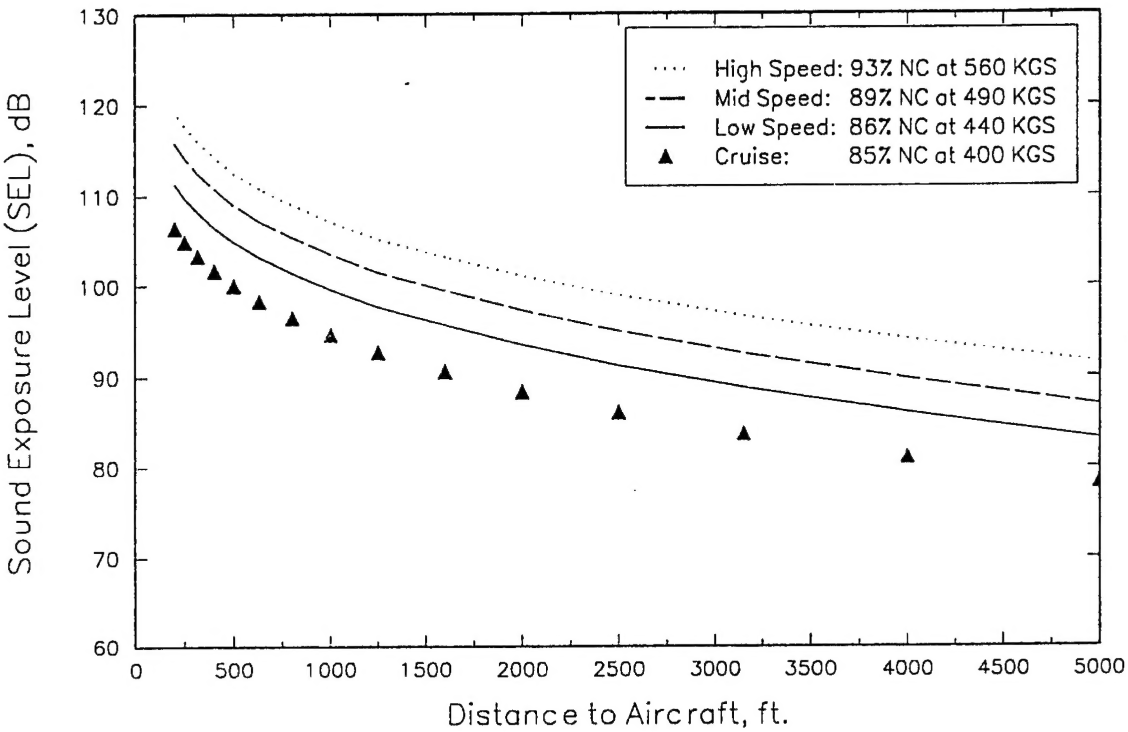


(c) F-15E Over Microphone Array.



(d) F-4G Approach.

Figure A-3 (Continued).



Distance to Aircraft, Ft	High Speed 93% NC 560 KGS	Mid Speed 89% NC 490 KGS	Low Speed 86% NC 440 KGS	Cruise 85% NC 400 KGS
200	119.3	115.8	111.3	106.4
250	117.7	114.2	109.8	104.9
315	116.0	112.5	108.2	103.3
400	114.3	110.8	106.5	101.7
500	112.5	109.0	104.9	100.0
630	110.8	107.2	103.2	98.3
800	109.0	105.4	101.4	96.5
1,000	107.1	103.5	99.6	94.6
1,250	105.2	101.5	97.7	92.7
1,600	103.2	99.5	95.7	90.6
2,000	101.1	97.3	93.5	88.4
2,500	98.9	95.0	91.2	86.1
3,150	96.6	92.5	88.8	83.7
4,000	94.1	89.8	86.1	81.1
5,000	91.5	86.9	83.2	78.3

Figure A-4. SEL Versus Slant Distance for the F-16C, Block 52 Aircraft for Air-to-Ground Sound Propagation.

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